THE TECHNO-ECONOMIC RELATIONSHIP BETWEEN INDUSTRY AND THE SCIENTIFIC INFRASTRUCTURE - WITH SPECIAL REFERENCE TO THE ELECTRONICS INDUSTRY AND SCOTTISH ECONOMIC DEVELOPMENT.

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I declare that this thesis has been composed by myself and that the work incorporated in it is my own.

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SUMMARY

This thesis is concerned with the pattern and extent of relationships existing between the scientific infrastructure - i.e. the network of public and semi-public institutions whose primary interests lie in research in the natural and applied sciences - and industrial activity. It has a regional bias insofar as emphasis is placed upon the role of the scientific infrastructure in helping to promote growth at the regional level.

An analysis is made of the role of investment in research and development (R & D) in the context of industrial production and its relative importance as a factor in economic growth. While this seems to be slight, R & D appears to play a significant part in the competitive strategy of firms within given industries. At the same time the scientific infrastructure acts as an important source of new technologies and to the extent that any region is poorly represented with respect to a scientific infrastructure, firms in this region may be at a competitive disadvantage, resulting in a poor regional growth performance. This in turn could be due to the fact that physical distance from outside research bodies increases the costs incurred in acquiring these technologies and reduces awareness of their existence.

These ideas are applied to the Scottish economy which is underrepresented in terms of a scientific infrastructure and has an industrial structure which is biased in favour of non-science-based industries. It is also an example of a relatively underdeveloped region within the wider U.K. economy. An empirical investigation is made of a small sample of firms in the electronics industry with respect to the nature and extent of

their relationships with the scientific infrastructure and whether or not the pattern of these relationships exhibits regional clustering. In order to facilitate the research, the sample is split into two sub-samples, one taken from central Scotland and the other from the south-east of England.

CHAPTER I

INTRODUCTION

In recent years there has evolved a growing interest in the economic and social impact of science and technology, an interest which has in a very real sense transcended standard intellectual disciplines insofar as science and technology are recognised as having become deeply implicated in a variety of pressing social problems.[1] However, from the point of view of understanding the true relationship between science and society, the starting point has usually been from within existing disciplinary structures, utilising the tools and methodologies developed by these structures in order to clarify the issues and relationships involved. In economics there appear to have been two basic approaches. On the one hand a number of economists have tried to develop a broad 'political economy' of science and technology. On the other emphasis has been placed on science's role in improving and enhancing economic efficiency by means of detailed studies on the generation and diffusion of new technologies at firm, industry and national levels.

An example of the former approach is contained in the recent work of Galbraith,[2] who regards technology as a key explanatory variable in his analysis of the workings of much of contemporary industrial production. Central to Galbraith's thesis is the proposition that the effective application of science to production requires the subdivision

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[1] Technological unemployment, pollution of the environment, nuclear, chemical and biological armament developments, to name but a few.

[2] J.K. Galbraith, 'The New Industrial State', (Harmondsworth, Pelican, 1969).

of tasks into their component parts, and that this specialisation of function is likely to increase in importance the more sophisticated does technology become.[3] In other words, one cannot apply technology to the production of a machine per se,[4] but one can to the various components and raw materials that go to make up the machine. This proposition has the following implications:

(i) An increased time span between the initial decision to produce and the first production run.

(ii) A concomitant increase in the commitment of capital to the production process.

(iii) An increased complexity of the production process which in turn requires greater organisational skills.

(iv) Greater risks.

(v) As a consequence of these, the increased necessity for careful planning and tight control of the whole of the manufacturing operation, including control of markets and factor supplies.

These features, according to Galbraith, provide a first-order explanation of a number of characteristics of modern industrial

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[3] It is clear that Galbraith draws heavily on the writings of the 18th and 19th century economists, notably Smith and Marx. Marx, in particular, was fairly systematic in his approach to science and production, drawing an important distinction between simple 'manufacturing' production and 'machine-intensive' production. While productivity of labour would improve under the former due to specialisation of function and the use of simple tools, science and technology could be applied to production on a large scale only when man had learned to make "machines to make machines". Once the link between the worker and his product had been broken in this way enormous increases in production were possible. For an interesting discussion on this and related topics, see C.M. Cooper, 'Science, Technology and Development', to be published in the Economic and Social Review, (1971).

[4] Except, of course, in the trivial sense that quality control requires a scientific input.

production, in particular the large size of firms, industrial concentration and monopoly, increased expenditures on advertising and large investments in research and development (R & D); and while, quite clearly, his ideas require very much more clarification and articulation than they have so far been given,[5] they do provide important insights into how technology is applied to production, and what sorts of problems arise as a result of this application.

The second approach appears to have stemmed from two factors, the view that technological change is a key factor in economic growth and the undoubted fact that western economies are devoting large volumes of resources to investment in science. At the government level this has served to focus attention on 'science policy'; that is the endeavour to set up policy criteria for deciding how funds should be allocated over the various areas of science spending. How much, for example, should be spent on elementary particle physics research relative to other branches of pure science? Should higher education be geared more towards the production of engineers and less towards the production of pure scientists? How can action at the government level help to improve the technical performance of British industry? And so on. Questions of this type are being asked increasingly by policy-makers as a result of the growing sophistication and complexity of modern scientific research and of the greater role which technology is playing in much of contemporary production.

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[5] For example, one important criticism is that in a number of industries, particularly those connected with electronics, very small science-based firms can, and do, exist in successful competition with much larger firms. Also, in the United States at least, industrial concentration does not appear to have increased markedly over recent years. See R.L. Heilbroner, 'The Limits of American Capitalism', (New York, Harper Torchbooks, 1967).

But this requirement for properly conceived policy action implies the ability to identify and describe the relevant decision-making variables and their inter-relationships. And it is precisely here that considerable problems arise, due fundamentally to the difficulty in 'pinning down', for analytical purposes, science and technology as a national resource. From the standpoint of an economic analysis of this area,-i.e. the costs and benefits associated with the production of scientific knowledge - this difficulty relates to the complex nature of scientific advance, certain peculiarities in the 'market for knowledge' and the consequent problems involved in first specifying the important relationships and subsequently quantifying them. The following points, while not by any means intended as an exhaustive list, give some indication of the types of problems involved:

(i) To begin with 'technology' and 'knowledge' are generic concepts covering a wide range of different technological 'elements' all of which are, to a greater or lesser extent, germane to the production process. For example, in any given industry there will normally be a wide range of scientific disciplines which are relevant, and each of these will exhibit a variety of 'mechanisms' through which the necessary technological elements may become available to the entrepreneur. To be more specific, knowledge may take the form of information flows, capital-embodied techniques, the stock of skills possessed by employees, the accretion of these skills through training and on-the-job learning, and so on. And within these broad forms a variety of 'sub-mechanisms' are easily discernible. Information flows, for example, may take the form of blue-prints, manuals, data sheets, abstracts, etc. These may arise from within as well as from outside the firm, and in the latter case can arise from a variety of different sources.

(ii) In the second place there are considerable problems in quantifying technology as a resource since there is no well established market for knowledge. Consequently knowledge, and more importantly its various elements, does not in general have a readily identifiable price.[6] Attempts have been made to measure the output of knowledge by measuring costs of invention and innovation using R & D investment data, but aside from the problems involved in accurately costing an R & D programme there are further difficulties insofar as 'input' measures are not in this case adequate measures of 'output' value[7] and because it is not generally possible to identify those elements of cost which relate to specific elements of differentiated knowledge - at least not without a great deal of effort and rather strong assumptions. Thus the very heterogeneity of this commodity renders the collection of adequate data on particular elements a difficult and time-consuming task.

(iii) Also, market imperfections exist to the extent that not all relevant technologies are known about. From the point of view of the investment decision-maker such imperfections can create large uncertainities in costing an R & D programme since he will be uncertain about which elements of technology are known (and their likely costs), and which will have to be the object of 'in-house' research. In addition the costs of 'in-house' research are very often underestimated because unanticipated problems obstruct the research effort.[8]

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[6] In some cases, of course, it is possible to patent knowledge, but even here this 'price' rarely reflects its marginal costs of production. More usually patents are seen as monopolistic incentives to innovation.

[7] Because, for example, many of these inputs are free goods to the firm.

[8] And, of course, these obstructions are by-products of the normal research programme. See, for example, A.W. Marshall and W.H. Meckling, 'Predictability of the Costs, Time and Success of Development', in '<u>The Rate and Direction of Inventive Activity</u>', (N.B.E.R., Princeton, 1962). Using data on military projects the authors find unanticipated cost increases of between 200-300%, and time extensions of $\frac{1}{3}$ to $\frac{1}{2}$ original estimates.

(iv) Finally, uncertainities exist in terms of returns to research. Hence even if an R & D programme produces new technologies at reasonable cost these, when incorporated into the production of a final product, need not be sufficient to ensure the product's success. In the case of nationally orientated projects, such as the British proposal to take part in the construction of the CERN 300 Gev Synchrotron, the returns also involve political, military, scientific and external economic factors, so that the uncertainities are compounded.

Nevertheless, despite these difficulties, it is clear that heavy emphasis must be placed in research in this field if only because of the necessity to make enlightened decisions on matters relating to the socio-economic use of science and technology. This thesis follows the second approach in an endeavour to shed some light on one sub-sector of the problem.

Specifically I am concerned with the role of research and development activities, carried on within the scientific infrastructure - the network of public and semi-public institutions whose interests focus on R & D, higher education in science and technology, information gathering and distribution, and technological extension services to industry - in helping to promote economic development, particularly that of declining regions within an industrialised economy. It is apparent that there are wide regional differences in industrial structure within the United Kingdom and that such imbalance may affect the ease with which any particular region - with an unfavourable structure - can attain a high and stable rate of growth. It is also a well known argument - indeed almost a tautology - that a region which is underrepresented by fast-growing industries is liable to face the prospect of a declining rate of growth coupled with many of the other facets of relative stagnation, (for example, higher than average unemployment, net emigration of skilled manpower, etc.), and that policy measures to remedy this situation may be necessary.

Without going into the subject in detail, the dynamics of the process are clear. As demand shifts in favour of industries which are under-represented in the underdeveloped region, investible resources move into these industries and a reverse multiplier effect come into operation. Incomes fall in the underdeveloped region causing further reductions in demand and so on. The fall in incomes reduces the local tax base, thereby reducing the level of social expenditure and considerably increasing the difficulties involved in dealing with the social problems which are part and parcel of the phenomenon of underdevelopment. Not the least of these is the problem of structural unemployment which itself is often reinforced by lack of labour mobility and the fact that unemployment tends to be dominated by unskilled labour, or labour whose skills are uniquely tied to the declining industries.[9] Conversely, qualified scientific manpower (Q.S.E.) and other forms of labour with

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[9] This is not to say that there are not other problems. Poverty, urban squalor (slums) and acute family problems are examples of social diseases - stemming partly, it is true, from unemployment - which any social worker or local government official will testify to. Particularly important from the point of view of attracting new industry into the region are the various elements of social overhead capital which industry requires to operate efficiently; viz. adequate transportation facilities, docks, electric power, an efficient capital market and so on. To the extent that these elements are financed by the local tax base the problem is clear. A lack of adequate facilities will make existing industry less competitive with other regions and will provide a further disincentive to new firms.

skills which are relevant to the expanding industries, do not seem to demonstrate a parallel immobility and there is evidence to suggest that it is precisely this type of labour which dominates, in proportional terms, net emigration rates. Finally such a decline in the relative skill base in the region may well be accompanied by cultural diseconomies (e.g. social amenities) which could make it difficult to attract this type of labour back.

Why and how this self-reinforcing process starts initially is a complex problem, but in a general sense a number of factors are commonly recognised. New industry may site itself close to some important raw material source or close to a well established supplying industry (such as engineering). Close proximity to a large market may be important in cases where transportation costs per unit of sales tend to be high (as, for example, with extremely bulky equipment). Nearness to suitable port facilities, a large metropolis with all the attendant social and economic advantages that this provides, a viable capital market and an abundant supply of suitably trained, or trainable, labour are other factors mentioned in the literature as variables which affect the location of industry. Myrdal makes the point that by and large "the power of attraction... of a centre has its origin mainly in the historical accident that something was once started there..." and that once this centre has become established, for whatever set of reasons, external and internal economies ensure its rapid growth at the expense of other regions or centres which were, perhaps, not so 'lucky' in the first place.[10] The process is self-inductive. The rich regions become

[10] G. Myrdal, 'Economic Theory and Underdeveloped Regions', (University Paperbacks, 1964), pages 26 and 27. Myrdal goes further in /cont.

richer, the poor poorer, and in the absence of government intervention profound regional inequalities are liable to result. This sequence has been explicitly recognised in the United Kingdom insofar as over the past 30 years the government has increasingly taken steps to promote regional economic development.

This thesis addresses itself to the question - are there factors of a scientific and technological character which reinforce these regional pressures? Certainly it is clear that many of the so-called 'growth' industries like electronics, food processing, pharmaceuticals, scientific instruments and petrochemicals are industries characterised by advanced levels of technology. There is also evidence that such industries are underrepresented in depressed regions of the United Kingdom and, while this may be due to 'normal' locational factors, it is possible that there are important technological influences at work which, in Myrdal's terms, act so as to reinforce the imbalance. It is suggested that one such influence may be the regional distribution of the scientific infrastructure which nowadays acts as a significant source of new technologies for industry. To the extent that the effective application of these technologies to industrial production is conditional upon

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asserting that there is "no... tendency towards self-stabilization in the social system... In the normal case a change does not call forth countervailing changes but, instead, supporting changes, which move the system in the same direction as the first change but much further". A fortiori in the case of international inequalities. (See ibid, chapter 1. I broadly agree with this proposition although there may be long run countervailing tendencies at work which Myrdal ignores. Thus excessive concentrations in any high-growth region may, for example, produce external social diseconomies, such as urban congestion and pollution of the environment which may, in turn, stimulate a reverse sequence. However, there is little evidence that this is yet happening in industrialised countries.

close physical proximity between the technology 'producer' and the technology 'consumer', a region which is underrepresented in terms of a viable scientific infrastructure may find itself at a distinct competitive disadvantage compared with other regions. Thus not only will firms in this region find it difficult to compete with firms more favourably placed but plans to attract new science-based firms will be compromised at the outset.

Conversely, measures which are successful in attracting firms of this type into a region will produce a reverse self-reinforcing process involving scale effects of an economic and technological character. O'Sullivan, in his study on economic progress in the Cork region of Ireland, shows that the location of new science-based industries within a region, provided this is carefully planned, can produce complementary and rapid development. "This localisation of industrial activities creates linkages forwards and backwards and causes 'spin-off' industrialisation based on by-products utilization, components supply, specialized services... (and)..., concomitantly, the local labour force develops the sophisticated skills associated with the specific technologies and suitably oriented training..."[11] Evidently, the establishment of a viable scientific infrastructure within such a region

[11] A.C. O'Sullivan, 'Development of Science-Based Industry in the Cork Region', Technology Ireland, (1971). O'Sullivan takes as his main example the development of food processing in the Midleton area of Cork. In this case the main catalyst was the initial establishment of large-scale cold storage facilities by a Swedish firm. This encouraged entrepreneurs to move into the area and produced backwards linkages in terms of new firms setting up to produce food-processing plant. It also benefitted local agricultural production.

could play a vital part in consolidating and accelerating such developments in terms of, for example, education of suitably skilled manpower, the provision of specialised facilities and the generation of new advanced technologies.

The following chapters are an attempt to examine and articulate the relationships between industry and the scientific infrastructure, paying particular attention to these in the context of the Scottish economy. Chapter II deals with a fairly substantial portion of the literature concerning research and development expenditures and their impact on economic growth. In particular it is shown that while there is some doubt as to the quantitative importance of investment in research as an explanatory factor in past growth, it does appear to become significant when examined as a vehicle for competition. Three issues are involved here:

(i) Overall, R & D investment may well be a largely determined phenomenon, determined by a number of factors such as long-run shifts in demand patterns, changes in industrial structure towards a pattern of industry which is more dependent upon 'science', economic growth itself, international competition and increased expenditures on armaments which have an innate tendency towards technological sophistication.

(ii) Nevertheless, while for any industry at any point in time the relevant technology may be largely <u>given</u> to firms as a datum, marginal differences in R & D investment among firms may influence competitive performance. Certainly such a theory is consistent with the evidence currently available.

(iii) Finally, therefore, there are a priori grounds for suspecting that the same process may hold at a regional level; viz. there may be influences which operate so as to reduce the level and/or efficiency of investment in, or utilisation of, 'science' in a region, and this phenomenon, if it exists, could lead to a general lack of competitiveness on the part of firms in that region, resulting in a variety of problems connected with inter-regional imbalance.

Chapter III takes up this last point and expands it. To begin with it is shown that there is some evidence pointing towards a tendency for the scientific infrastructure to concentrate itself geographically. There is also some more limited evidence suggesting that science-based firms are attracted to these locations. To the extent that this holds true, it would appear that there are advantages associated with close contact between the scientific infrastructure on the one hand and science-based industry on the other. These advantages are expressed firstly through a theoretical analysis of differential costs of technology to firms, due to physical distance and inefficiencies in scientific communications. Subsequently they are articulated into the types of advantages which we should expect to exist. Chapter IV goes on to deal with Scotland as an example of a region behind-hand in terms of industrial structure, but one which has recently made attempts to modernise its industrial base. A critical examination is made of the Toothill Report[12] and its comments on 'science' in Scotland, using a rough statistical analysis of regional R & D data. It would appear that R & D spending in Scottish

[12] J.N. Toothill, (chairman), 'Inquiry into the Scottish Economy', (Edinburgh, 1961).

industry has tended to fall in recent years and has always been well below national levels. And this seems to be the case even when taking into account relative industrial structure. Possible reasons are suggested as to why this pattern exists, but the tentative conclusion is that not only does science-based industry find it unprofitable to operate in Scotland but, even where it does, the 'technological intensity' of production is very much below U.K. levels.

The arguments developed in Chapters III and IV suggest that there may be a link between the concentration of outside research bodies in the south-east of England, the industrial structure of Scotland and the poor research performance of Scottish industry. Specifically, it may be the case that a better developed scientific infrastructure in Scotland could play an important role in firstly improving the competitive performance of existing industry and secondly attracting new science-based firms to Scotland. This could be especially important with respect to small firms since larger firms are often able to support their own R & D departments and are consequently able to generate their own new technologies.

From this discussion two basic hypotheses emerge:

(i) <u>That geographical distance from research institutions significantly inhibits the ease with which private industry may maintain contacts with these institutions and that this will be reflected in the extent of contact actually made</u>.

(ii) <u>That this situation has a significantly deleterious impact upon the effective research capacity of science-based industry in Scotland and consequently upon the rate of growth of such industry</u>.

These hypotheses were made the focus of an empirical study of a small sample of electronics firms. The sample was split into two sub-samples, one from central Scotland and the other from the south-east of England. The objective was to determine the nature and extent of contact between these sub-samples and the scientific infrastructure in order to shed some light on the hypotheses mentioned above. Chapter V discusses the methodology used in this study, while Chapter VI presents the detailed empirical evidence uncovered. Finally, Chapter VII summarises the conclusions which can be drawn from this thesis and makes a number of suggestions for further research.

CHAPTER II

RESEARCH AND DEVELOPMENT, TECHNICAL CHANGE AND ECONOMIC GROWTH

1. Introduction

In recent years countries in Western Europe and North America have experienced considerable growth in expenditure on science in general and on science related to industrial activity in particular. In the United States, for example, private industry spent a total of $10.9 billion on R & D in 1961, $2.2 billion in 1951, $0.4 billion in 1940 and $0.2 billion in 1931.[1] Similarly in Great Britain industrial R & D expenditures increased by some 2½ times between 1956 and 1965, while between 1946 and 1967 budgetary levels of government spending on civil research and development increased from £6.6 million to £258.5 million.[2] Quite clearly these substantial increases require both justification and understanding in terms of economic and social factors, in order to delineate the precise role that R & D plays, or is expected to play, in modern industrial economies and in order to comprehend the various social and economic forces that have brought such a situation about. In fact the literature, both empirical and theoretical, on the subject has also increased substantially in recent years and, on the whole, testifies to the assertion that this is a highly complex area of enquiry.

In this chapter I shall be examining one particular section of this area, which besides being of general interest has important implications

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[1] D. Hamberg, 'Essays on the Economics of Research and Development', (New York, Random House, 1966). Hamberg draws his material from a variety of government and private sources.

[2] Council for Scientific Policy, 'Report on Science Policy', (London, HMSO, 1966), Cmnd.3007.

for the empirical work discussed later on. This area centres around the relationship between R & D expenditures on the one hand and economic growth on the other. Clearly the importance of R & D in a regional context is predicated upon its overall importance as a stimulus to technical change and economic growth, since if we come to the conclusion that R & D expenditure is of minor importance in the development process then its regional impact (or lack of impact) will be that much less crucial.

To begin with a critical examination is made of a number of theoretical and empirical studies of the contribution of R & D to economic growth at the levels of economy, industry and firm. The general picture that seems to emerge is that while at the macro-level there is little evidence that R & D is an important contributary factor, at the micro-level firms' spending on R & D does affect performance. This apparent contradiction is explained with reference to a simple model of the research process which lays emphasis on the hypothesis that spending at the firm level is largely motivated by short term, defensive considerations and by the scientific receptivity of the industry in question. A further explanation is supplied through the consideration of R & D as an effective measure of genuine innovative activity, since to the extent that it is not we should not expect R & D to impinge greatly on technological change and hence upon economic growth. This discussion leads on to the tentative conclusion that R & D as measured may be largely a determined phenomenon to be regarded as a short term input in the productive process rather than a measure of long-term innovative activity. Nevertheless, at the level of the firm, and by extension the region, it is clear that it would be unwise for any firm to fall below an optimum level of research spending, if only since the necessity for keeping up with current trends is an important condition for success in a technologically-based industry. Similarly at the regional level, if there are factors such as geographical distance from important centres of excellence which place a particular region at a competitive disadvantage, then that region may suffer correspondingly. However, a detailed discussion of regional aspects is reserved for the following chapter.

2. The Macro-Context

The Residual

A number of writers have noted on examination of long term trends in national productivity (national income per head) that only a relatively small proportion can be explained through increases in the stock of capital, the remainder being classified as 'technological progress', 'the residual', 'shifts in the aggregate production function', 'improvement in productivity' and a variety of other forms of terminology designed to emphasise the 'unexplained' nature of the concept. Thus Solow,[3] for example, in an analysis of U.S. manufacturing industry between 1909 and 1945 attributes only 12.5% of improvements in labour productivity to increased capital input and Johnston[4] comes to the general conclusion, based on an examination of empirical studies in the U.S., that some 80-90% of increases in labour productivity can be attributed to technical progress. Denison,[5] examining the period 1929 to 1957 estimates a residual of only 52%, but this does not include

[3] R. Solow, 'Technical Change and the Aggregate Production Function', Review of Economics and Statistics, August 1957.

[4] R.E. Johnston, 'Technical Progress and Innovation', Oxford Economic Papers.

[5] E.F. Denison, 'The Sources of Economic Growth in the United States and the Alternatives before us', (New York, Committee for Economic Development, 1962).

quality improvements in labour and capital. The important point, however, is that the bulk of long term economic growth in the U.S. economy during the past half century has been due to increased efficiency in utilising resources and to the discovery and application of better ways of doing things.

It is not at all surprising, therefore, that attempts have been made to ascribe the causes of this 'unknown residual' to that form of organized inventive activity which is summarily called Research and Development. After all, if economic growth is caused largely by discoveries of 'better ways of doing things', then investment in this must surely pay off and, indeed, since industrial R & D expenditures have been increasing markedly in recent years, it is intuitively plausible to suggest that this must be one of the major factors involved. Thus Ewell[6] points to a high correlation between U.S. Gross National Product and National R & D expenditures over the years 1925-1953 and Freeman[7] reaches similar conclusions for both the U.S. and the U.K. over the period 1935-1958. Ewell in particular becomes quite enthusiastic over his findings concluding that "The United States has probably the highest economic growth rate among the highly industrialised countries of the world. The United States is also distinguished by devoting the highest percentage of its national income to research and development. There is a definite correlation between these two facts. Research is a highly creative activity - it produces new products, creates new jobs and new industries, cuts costs of production, and makes a large contribution to our economic growth and our over-all national welfare.

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[6] R.H. Ewell, 'Role of Research in Economic Growth', Chemical Engineering News, Vol.33, No.29, July 1955.

[7] C. Freeman, 'Research and Development: a Comparison between British and American Industry', N.I.E.R., May 1962.

Research is the spearhead of economic growth in a modern industrial nation".[8] Such statements illustrate the dangers of becoming carried away by simple correlation analyses which say nothing about causality or about the possible influence of exogenous factors, and suggests the importance of delineating the role of R & D in its true perspective.

Freeman analyses research expenditures/net output in 1958 as a function of growth for seventeen industrial groups in the United States and Great Britain over the years 1935-58. He finds high and significant correlation coefficients for both countries and points to this evidence as indicating that R & D is an important contributing factor to economic growth although he cautions that "the link between research expenditures and technological progress is not simple."[9] However, it is clear that simple correlation coefficients of this kind only point to an association and say nothing about causality. In fact correlating end-period research figures with growth output during the period would suggest that if anything the latter caused the former and point towards a theory indicating that fast growing industries are better able to afford the luxury of R & D departments. What is equally plausible is that other factors, such as changing structures of final demand, have led to the growth of industries which are by their very nature 'science-based' and which require a certain volume of R & D 'back-up'. This will be discussed in more detail below.

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[8] Ewell, op.cit, p.2980. In practice Ewell pays ritual obeisance to the lack of causality implied by correlation coefficients, but the whole tenor of his argument implies that R & D is a major source of improvements in national productivity. cf. also his diagram on p.2983 which if anything shows the reverse causality. Finally, Ewell's own predictions for R & D expenditures in 1960 turn out to be well over 100% wrong.

[9] C. Freeman, 'Research and Development: a Comparison...', op.cit.

Finally, Freeman, Poignant and Svennilson come to the conclusion that "despite all the factors which concur to increase the level of R & D activity, there are serious reasons for believing that this level is in many cases inadequate for sustained and rapid economic growth".[10]

The Empirical Evidence

What evidence exists to link R & D expenditures to economic growth? Kendrick[11] cites the work of Terleckyj[12] who attempted to explain long term changes in total factor productivity[13] in the U.S. economy using regression techniques. Terleckyj regressed R & D expenditures/sales and R & D manpower/total man-hours against productivity changes for 20-2 digit and 25-3 digit industries. He found a significant fit but one which left a large unexplained variance. His net regression coefficients indicate that rates of productivity advance differ by approximately 0.5% for each tenfold difference in research intensity. A certain amount of criticism must be attached to this study since it ignores difference in "scientific receptivity"[14] between different industries. Nor is allowance made for the effect of R & D in one industry on productivity changes in another. Nevertheless it is clear that the influence of R & D

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[10] C. Freeman, R. Poignant and I. Svennilson, "Science, economic growth and government policy', (Paris, O.E.C.D., 1963).

[11] J. Kendrick, 'Productivity Trends in the U.S.', (N.B.E.R., 1961).

[12] N. Terleckyj, 'Sources of Productivity Advance', Ph.D. thesis, Columbia University, 1960; quoted in Kendrick, op.cit.

[13] Total factor productivity is defined as output per unit of labour and capital input. Capital and labour and weighted by their relative prices in the base period.

[14] "Scientific receptivity" is defined as the degree to which an industry is susceptible to Research and Development Effort. Clearly an industry such as electronics requires a much higher R & D "back-up" than, say, textiles. One might have expected Terleckyj to allow for this in his study.

expenditures, whilst it exists, is in fact a very minor one. Similarly Denison, in his statistical analysis of the sources of economic growth in the United States concludes that while 36% of long-term growth in national income per head can be ascribed to the "advance in knowledge" onle 12% of this - i.e. around 4% of total growth - can be laid at the door of organised R & D. This conclusion agrees remarkably closely with that of Terleckyj.

In addition, Hamberg remains sceptical of the contribution of R & D and is worth quoting at length. "One of the interesting features of the recent research explosion, of the technological revolution, is that it has thus far failed to show up much in the estimates of productivity growth. It is true that the growth rate of output per man-hour of 3.2 per cent a year for the period 1947-64 was well above the long-term 2.4 per cent rate of increase. But it is also true that similarly high rates of productivity growth occurred in earlier periods for comparable lengths of time, and before the research explosion. And it is also true that the recent surge has been induced primarily by the great spurt in the growth of productivity in agriculture, where the reasons have had relatively little to do with the boom in research and development. In the 1947-64 period, productivity in the non-farm, private sector grew at an average annual rate of 2.6 per cent, versus a long-term growth rate of 2.3 per cent. In manufacturing, where R & D is concentrated, productivity advanced at the average rate of 2.8 per cent a year, compared with a 2.7 long-term rate of increase"; and again, "Why productivity growth has lagged behind the great swell in R & D is hard to say, and efforts to evaluate the former in terms of the latter may be a bit premature."[15]

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[15] D. Hamberg, op.cit., page 4.

Again Solo[16] in an analysis of the civilian implications of military R & D, examines the long-term relationship in the U.S. economy between rate of change of labour productivity (output per man hour) and R & D expenditure as a percentage of national income. He finds practically no correlation and similar results hold true when R & D expenditure/national income is compared with rates of change of national income. Solo goes on to explain that this data does not necessarily mean that R & D is unproductive. His explanation is that there are unspecified barriers to economic growth which prevent the fruitful outcome of R & D expenditures. These might be, for example, changes in the conditions of money supply, changes in savings habits, taxation levels and wars. However, his main explanatory point is that increasingly in the United States economy the bulk of R & D is devoted to space and military objectives, and as the complexity and uniqueness of scientific apparatus increase the possibilities for 'spin-off' into civilian uses decrease. Hence the minimal impact on measured economic growth.

Correspondingly Terleckyj[17] finds for greater explanatory power in his scale variable, showing that a 3% growth rate in industrial output affected measured productivity changes by 1%. Kendrick places emphasis upon changes in cultural values and economic organisation, changes which "enable and promote the pursuit of efficiency"[18] while Denison also gives emphasis to improvements in education.[19] Clearly the issue is by no means settled and more comprehensive empirical work is required but we may conclude tentatively that the 'case' for R & D as an important

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16 R.A. Solo, 'Gearing Military R & D to Economic Growth', <u>Harvard Business Review</u>, Nov-Dec 1962.
17 <u>op.cit.</u>
18 <u>ibid.</u>
19 <u>op.cit.</u>, chapter 7.

explanatory variable seems to be very weak indeed, certainly at the macro-level. What follow are certain suggested reasons as to why this may be so.

Possible reasons for Low Impact of Measured R & D

(i) The Relative Importance of Other Factors: Some of these were mentioned in relation to the empirical studies discussed above, while a number of writers have examined and suggested a whole series of hypotheses. Thus Williams[20] maintains that productivity growth may depend upon such factors as changing concentration of industry, management aptitudes, alternative uses of scientists and technologists. Kaldor[21] places emphasis on economies of scale and maintains that the two most effective constraints on economic growth are commodity restraints (usually reflected in balance-of-payments deficits and the resultant short-term curbs) and lack of adequate labour reserves. A variety of other factors such as increased utilization of capacity, improvements in shift-working, improvements in banking and other service facilities have also been mentioned. However, the only comprehensive piece of empirical work dealing with the subject is that of Denison[22] who undertook a detailed statistical study of the source of economic growth in the United States between 1929 to 1957.

Denison starts with an annual growth rate of 2.93% of real national product in the U.S. between 1929-1957. Of this he claims that 2.00% can

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[20] B.R. Williams, 'Research and Economic Growth - What Should we Expect?', Minerva, Autumn 1964.

[21] N. Kaldor, 'Causes of the Slow Rate of Economic Growth of the U.K.', (London, C.U.P., 1966).

[22] E.F. Denison, op.cit., chapter 21.

be ascribed to increases in inputs, the remainder being due to growth of output per unit of input. The 2.00% is made up of 0.43% due to increases in the capital stock, and 1.57% due to increases in the labour supply adjusted for improvements in quality. This latter factor is made up of a number of influences, the effect of shorter working hours, better utilization of women workers and education being the main ones. The 0.93% of productivity growth is made up largely by the effects of economies of scale, 0.34% and 'advances of knowledge', 0.58%. Of this Denison is able to ascribe only 0.12% to the impact of organised R & D. Interestingly enough, therefore, his conclusions are that over this period R & D was a relatively minor influence on measured economic growth in comparison to others such as economies of scale, education and the sheer physical influences of labour and capital increases.

(ii) The Measurement of Productivity Change: There are basically two types of measure, labour productivity measures corrected usually for shifts in hours worked and the total productivity index which consists of output per unit of total input, the input being a weighted aggregate of capital and labour flows. The former suffers from the obvious disadvantage that it ignores capital movements although, surprisingly enough, there seems to be a certain amount of evidence to suggest that for cross industry studies at least the two measures are fairly highly correlated. Both Kendrick[23] and Stigler[24] show correlation coefficients of between 0.8 and 0.9. For time series estimates the two measures will be correlated to the extent that technological change is neutral, as

[23] J.W. Kendrick, op.cit.

[24] G.J. Stigler, 'Economic Problems in Measuring Changes in Productivity', in 'Output, Input and Productivity Measurement', (Princeton, U.P., 1961), (N.B.E.R. Studies in Income and Wealth).

assumed by Solow[25] in his analysis of technical change and the aggregate production function for the U.S. economy between 1909 and 1949. Solow's regression analyses produced a good fit for each of a variety of production function specifications assuming technological neutrality and marginal product payments to factors. To the extent that technological change is not factor neutral, of course, simple analyses like that of Solo[26] are called in question. Mansfield[27] points out that measures of technological change which are in fact 'capital-embodied' produce different results. Such measures assume that part of technological change is due to improvements in the quality of capital and give quantitatively larger estimates of technological change. However, it is clear that technological change is also labour-embodied in the sense the improvements in quality of labour have undoubtedly contributed significantly to total productivity changes over the years.[28]

There are a number of other factors which suggest extreme caution in the treatment of existing measures of technological change. A lot depends on the initial assumptions made. Thus Stigler,[29] Jorgensen and Griliches[30] have pointed to a number of problems associated with the choice of prices for capital and labour inputs and have laid particular emphasis upon the difficulties involved in measuring capital services. In particular Jorgensen and Griliches have tried to show that conventional measures of technological change have seriously understated

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25 R. Solow, 'Technical Change and the Aggregate Production Function', op.cit.

26 R. Solo, 'Gearing Military R & D...', op.cit.

27 E. Mansfield, 'The Economics of Technological Change', (London, Longmans, 1968), see chapter II.

28 Denison in particular gives a lot of emphasis to this factor. See op.cit, chapter 7.

29 G.J. Stigler, op.cit., pages 50-54.

30 D. Jorgensen and Z. Griliches, 'Sources of Measured Productivity Change: Capital Input', A.E.R., Papers and Proceedings, Dec. 1965.

the contribution of capital, thus overstating the productivity index and understating the contribution of R & D in terms of, say, Terleckyj's regression coefficients. Denison[31] has criticised this conclusion - i.e. of the underestimate of capital services - on the grounds that the increased contribution of capital assumed by Jorgensen and Griliches does nothing more than take into account improvements in the quality of capital. All, therefore, that the authors are doing is to draw a semantic distinction. Denison seems to imply that a Terleckyj-type study using the Jorgensen/Griliches method of determining total productivity indices would reveal an even lower contribution of R & D - if any - since such a contribution would tend to reveal itself precisely through these improvements in quality of capital which the authors wish to 'iron out' of the old indices.

Stigler[32] has questioned the instrumental nature of the index and has shown that by taking 'base year' prices of capital and labour - so that factor input in period 2 is measured at prices ruling in period 1, thereby reflecting the technology in period 1 - it is possible to observe a spurious decrease in productivity where in fact none has taken place, the decrease being caused by changing factor prices and corresponding reallocation of resources on the part of entrepreneurs. Clearly this type of bias will vary from industry to industry depending upon relative factor price movements, and equally clearly it places in question the type of analysis carried out by Terleckyj since had he corrected for price movements and factor reallocation, his measured effect of R & D might well have been different.

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[31] E. Denison, Comment on Jorgensen and Griliches; same ref.
[32] G.J. Stigler, op.cit., pages 50-54.

It is evident, therefore, as Mansfield[33] points out, that "we are a long way from having precise measurements of the rate of technological change". But there is little to suggest at present that on a priori grounds the effect of R & D would prove to be any greater were more precise measurements to be obtained.

(iii) Unmeasured Effects: A number of authors have pointed out that the impact of R & D may be felt in areas of economic and social life where objective measurements of cost and benefits cannot be made. Thus, Freeman, Poignant and Svennilson[34] discuss the 'non-growth' effects of R & D in terms of improved medicines and health techniques, improved weapons of destruction, pollution of the environment, improved social services and so on. Since very often output of this type has no market price, no accurate indication of increases in social benefit can be made. Certainly they are not generally picked up in conventional measures of economic output. Probably the most important area here is the effect of military R & D which as Solo points out seems to have very little spin-off into the civilian economy. To some extent, of course, R & D conducted for 'non-growth' objectives may have a certain impact on measured economic growth, an interesting example being the effects of improved diet and health on the productivity of labour force. To the extent that there are no such effects, however, any attempt to equate R & D output of this type with economic and social 'benefits' would involve very explicit value judgements as to the nature of the final output. Generally speaking very little can be said on this subject

[33] E. Mansfield, The Economics of Technological Change', op.cit., page 34.
[34] C. Freeman, R. Poignant and I. Svennilson, 'Science, Economic Growth and Government Policy', (Paris, O.E.C.D., 1963).

except possibly to point out that since the rapidly growing volume of space and military orientated R & D does not seem to have had a significant impact on the civilian economy, this may prove to be a partial explanation of the low contribution of R & D to economic growth.

(iv) Skewness of R & D Distribution: Since R & D is usually concentrated heavily amongst a relatively small number of industry groups, it has been suggested that we should not expect a high correlation between R & D and economic growth at the macro-level. Thus Hamberg[35] points out that in 1961, 59% of the U.S. industrial investment in R & D was concentrated in two industrial groups which together contributed only 6% of value-added. Hamberg also tends to discount the important objection to this; viz. that productivity improvements in low R & D sectors may well be caused by purchases from high R & D sectors (e.g. computers in the textile industry). He shows that manufacturing industry in 1961, while accounting for only 30% of national income in all industries, conducted 98% of all R & D performed by industry. Examining this high R & D sector he goes on to say that in 1958 "the purchases of (these) manufacturing industries... accounted for substantially more than half of inter-industry sales of... intermediate products plus fixed capital goods, and since as a group they account for less than a third of value-added by all industry, there is still probably considerable merit in the explanation."[36] Nevertheless it is clear that considerable improvements have been made in low R & D sectors (e.g. agriculture) by way of purchases from high R & D sectors, so that this explanation should be treated with some caution.

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[35] D. Hamberg, 'Essays on the Economics of Research and Development', chapter I.

[36] ibid., page 7.

(v) R & D as an Indicator of Innovative Activity: Here there is some confusion. Freeman[37], for example, states that 'figures of industrial research and development are probably the best quantitative indicators of invention and innovation" adducing in support the conclusion of Kendrick that "although we cannot measure it precisely, research and development activity is our best indication of the investment in scientific and technological advance that sooner or later results in productivity growth". However, Kendrick,[38] to the extent that he bases his conclusions on the results of Terleckyj, shows that while it is perfectly true that a significant correlation exists, the relationship in causal terms is very slight. The important question here is: how much research produces how much productivity growth? Results such as those of Terleckyj would appear to suggest that a 100% growth in research effort would raise the rate of productivity growth from, say, 2.00% to 2.08% which surely does not augur well for hopes pinned on "investment in scientific and technological advance that sooner or later results in productivity growth".

Hamberg,[39] on the other hand, tends to the opposite conclusion suggesting that as a measure of innovative activity, statistics on R & D score a rather low rating. He cites a number of studies such as those of Jewkes,[40] Grosvenor,[41] Mueller,[42] and Peck[43] which present considerable evidence in favour of the hypothesis that most 'major' inventions and

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37 C. Freeman, 'Research and Development: a Comparison...', op.cit., p.29.
38 J.W. Kendrick, op.cit., p.110; quoted in Freeman.
39 D. Hamberg, op.cit. See particularly pp.10-13 and chapter 5.
40 J. Jewkes et al, 'The Sources of Invention', (London, Macmillan, 1969).
41 W.N. Grosvenor, 'The Seeds of Progress', (Chemical Markets, 1929). cited in Hamberg.
42 W.F. Mueller, 'The Origins of the Basic Inventions Underlying Du Pont's Major Product and Process Innovations, 1920-1950', in 'The Rate and Direction of Inventive Activity', (Princeton U.P., 1962).
43 M.J. Peck, 'Inventions in the Post-war American Aluminium Industry', ibid., p.279.

innovations tend to originate outside large corporate laboratories. In contrast the R & D carried out within these laboratories tends to be concerned largely with making minor improvements and modifications to existing products and processes; and since the overwhelming bulk of R & D is carried out by large firms, it would seem logical to suppose that R & D statistics do not in fact give us a very good measure of innovative activity.

Further evidence for this 'defensive' approach on the part of large corporations comes from the McGraw-Hill study[44] in which 91% of firms interviewed expected a pay-back period of five years or less on R & D investment. Such a concentration of motivation with respect to short term 'pay-offs' would seem to indicate that the R & D conducted by large corporations does not contribute significantly to technological progress. Hamberg adduces other reasons such as, for example, the 'limitations of team research', arguing that where emphasis is placed upon cooperative research the 'pressure to compromise is continuously at work' leading to the least objectionable solutions to problems, ideas and/or techniques.[45] In Kuhnian terms the corporate researchers are constrained to operate within the rules of the game and are discouraged from attempting radical breakthroughs.[46]

I am forced to the tentative conclusion that Hamberg's approach may well be the correct one, in which case this provides another explanation of R & D's low measured growth impact.

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[44] Cited in D.M. Keezer, 'The Outlook for Expenditure on Research and Development During the Next Decade', A.E.R., May 1960.
[45] D. Hamberg, op.cit., chapter 5, p.105 and passim.
[46] See also C.F. Carter and B.R. Williams, 'Industry and Technical Progress', (London, OUP, 1957).

(v) Diminishing Returns to R & D: Finally, a consideration of the role of R & D as a defensive strategy leads to the hypotheses that the whole process may well be subject to diminishing returns. Thus to the extent that firms in a given industry compete on the technical sophistication of their products then their vehicle for competition will be R & D investment since this will be the source of minor improvements in design, capacity, robustness, performance and all of the many ways in which a product can achieve superiority over its rivals. The prevalence of this phenomenon will, of course, depend upon the degree of 'technical receptiveness' of the industry in question, but it is clear that as technology becomes more sophisticated and as industrial structure becomes increasingly 'science-based' the chances are that the sheer scope for such forms of competition will increase.

There is a certain amount of evidence against this hypothesis. Thus Brozen[47] examining the long-term trends in industrial research in the United States shows that between 1951 and 1960 there was a relative decline in the growth of R & D expenditures although in absolute terms and as a proportion of GNP it was still growing. He puts this phenomenon down to the proposition that by the end of the fifties the 'R & D industry' was,much closer to a long run equilibrium for a variety of reasons. One of the reasons, however, is the falling off in defence spending and since space and military spending rose rapidly in the early sixties, one would like to have further evidence on R & D growth for this period. Certainly other works performed by myself using international data appeared to show that R & D expenditures corrected for

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[47] Y. Brozen, 'Trends in Industrial Research', Journal of Business, (1961).

size increased as both the size of the economy and the change of industrial structure towards science-based industry.[48]

Clearly it is difficult to tell at this stage whether R & D expenditures have reached an optimum or whether they will continue to increase. More empirical research requires to be carried out. But the hypothesis that R & D expenditures may become inflated in this way certainly has a certain plausibility. Thus Brozen himself places a lot of emphasis upon the 'quality of the science base' as an explanatory factor for R & D differences amongst industries. Those industries which are intimately related to expanding fields in the natural sciences will have more fruitful prospects of productive R & D.[49] The obvious inference here is that R & D will continue to grow in modern industrial states to the extent that industry continues to become increasingly science-based. However, this need not imply diminishing returns to R & D. What it does imply is a theory of R & D expenditures which places more emphasis upon institutional factors. I shall return to this point later on.

I have tried to show that despite the conclusions of certain authors, the evidence seems to suggest that R & D as conventionally measured does not seem to be an important explanatory variable for economic growth at the macro level. Other factors such as improved education, economies of scale, improved capacity utilization, better health, improved management skills, etc. may well be more important. However, the evidence is not complete and clearly a more comprehensive empirical study might throw

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[48] Unpublished internal working paper.
[49] Y. Brozen, 'R & D Differences among Industries', in R. Tybout, (ed), '<u>The Economics of Research and Development</u>', (Ohio State U.P., 1965).

a different slant on the problem. The empirical evidence may be questioned on the following grounds:

(a) Existing measures of technological change are subject to error.

(b) They do not pick up the non-measurable aspects of social output.

(c) They do not always take into account cross-industry effects of R & D spending.

If it is agreed that in relation to others R & D investment is in fact a 'minor' contributer to economic growth, then how is this to be explained in view of the fact that R & D investment is widely regarded as a source of new ideas, techniques, products, etc? The following factors suggest themselves:

(a) R & D tends to be concentrated in only a few industrial sectors.

(b) R & D is a poor indicator of genuine innovative activity.

(c) Related to (b) it would seem that the bulk of corporate R & D is defensive in orientation, stressing short pay-back periods and concentrating upon minor modifications to already existing products and processes rather than major innovations.

The essence of this analysis is that is points towards a theory which stresses the <u>institutionally determined</u> nature of R & D expenditures at the macro-level. Firstly, much of modern industry requires a certain amount of R & D 'back-up'. One cannot produce a modern electronic instrument without having a department (or staff) to deal with circuit design, routine testing and so on. In this guise R & D becomes one more conventional input in the productive process. Secondly, to the extent that firms compete on sophistication of product, then we should expect R & D expenditures to increase as industry becomes more technologically based. This may or may not have, in the past, rendered R & D investment subject to diminishing returns. Nor does it preclude the possibility that R & D investment is after all a significant source of productivity growth as well. It does, however, suggest that it may be better to place R & D investment in a different perspective as a national resource. Before this is articulated further it will be necessary to examine a number of studies concerned with investment in research and development and the performance of firms.

3. The Micro-Context

So far I have discussed the relationship of research and economic growth at the macro-level. However, an examination of the relationship at the micro-level presents rather a different story. Thus, while here again the volume of empirical work is not substantial, what there is appears to suggest that for certain industries at least those firms which spend more on R & D tend to be more successful.

Mansfield,[50, 51] who has carried out an enormous amount of empirical work in this area, attempted to resolve the question of the productivity of R & D by performing regression analyses on the determinants of "significant innovations" in a number of U.S. industries.[52] In each industry the number of innovations, weighted by their respective relative importance (the weights being determined by interview data),

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[50] E. Mansfield, '<u>Industrial Research and Technological Innovation</u>', (Norton, 1968).

[51] E. Mansfield, '<u>The Economics of Technological Change</u>', (Longmans, 1969). Both this and the previous reference bring together much of Mansfield's work in this area over the past years.

[52] E. Mansfield, 'Size of Firm, Market Structure and Innovation', <u>J.P.E.</u>, (December 1963). See also reference 50, and Mansfield's paper in Tybout, 'The Economics of Research and Development', <u>op.cit.</u>, p.136.

per dollar of R & D expenditure is specified as a function of size (measured by sales) and R & D expenditures. He finds that when size of firm is held constant the number of significant inventions carried out by a firm seems to be strongly influenced by the size of its R & D expenditures. This is true of all three industries examined, chemicals, petroleum and steel. The relevant partial correlation coefficients are 0.96, 0.98 and 0.70 respectively. He concludes that while "the pay-out from an individual R & D project is obviously very uncertain, there seems to be a close relationship over the long run between the amount a firm spends on R & D and the total number of important inventions it produces".

He shows that when size of firm is held constant, increases in R & D expenditures result in more than proportionate increases in inventive output in the chemical industry. The corresponding evidence for petroleum and steel is not conclusive. Finally, when R & D expenditures are held constant "the average productivity of such expenditures turn out to be negative in each industry and statistically significant in two out of the three industries".

Two obvious criticisms of this study suggest themselves. Firstly, as Griliches[53] points out, the 'weighting' of innovations, while done according to an economic criterion, has a certain arbitrary character and may be subject to a wide margin of error. For instance, the 'informed observers' interviewed could well have been biased in a variety of ways, for example by the technical excellence of particular innovations. Secondly, because of differences in accounting procedures the R & D data

[53] Z. Griliches, 'Comment of Mansfield', in R. Tybout, '<u>The Economics of Research and Development</u>', op.cit., p.148.

used need not have been directly comparable. Mansfield, himself, admits both of these criticisms. Nevertheless, his conclusions do seem to point to a relationship between research and performance at the firm level.

In a further study Mansfield[54] attempted to obtain a theoretical expression for the marginal rate of return to cumulated past expenditures on R & D, assuming a Cobb-Douglas production function incorporating an expression for exponentially growing R & D expenditures, no uncertainty, and the fact that technological change is only cost-reducing. Applying this model to post-war data from ten large petroleum and chemical firms and, at the industry level, to ten manufacturing industries he found that at the firm level the rate of return was very high for the petroleum firms and high for the chemical firms if technological change was capital-embodied. At the industry level the rates of return were high in the food, apparel and furniture industries. However, Mansfield advises caution in interpreting these results in view of the fact that the theoretical model was evolved on the basis of a number of highly simplified assumptions. Finally, in a number of other studies Mansfield finds that models incorporating 'expected rate of profitability' explain quite well differences in the amount spent on R & D by firms and the rate of diffusion of innovations.

Minasian[55] went one stage further in that his study was an attempt to relate relative R & D spending to the actual profitability and productivity of firms rather than inventive output. In addition he

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[54] E. Mansfield, '<u>Industrial Research...</u>', <u>op.cit.</u>, chapter 4.
[55] J.R. Minasian, 'The Economics of Research and Development' in N.B.E.R., '<u>The Rate and Direction of Inventive Activity</u>'.

tested a number of lagged relationships in a manner which Mansfield, by the very nature of his study, could not have been expected to do. For eighteen chemical firms he evolved a total productivity index assuming an initial Cobb-Douglas production function and analysed the rate of the growth of this index against average R & D expenditures deflated by size of firm. He found a significant set of relationships which pointed to a strong lagged effect of R & D on both productivity growth and profitability. Furthermore he tested against spurious correlation because of high profitability leading to both high productivity and high R & D spending, and found that R & D at the beginning of the period explained end-period profitability far better than vice-versa. He also tested the alternative hypothesis that productivity growth is explained by differential rates of investment. This he also rejected. Finally scatter-diagrams for the same variables were examined for a small number of firms in the drug and pharmaceutical industries. These appeared to suggest similar relationships.

Clearly it is not permissable to infer too much from a study of a small sample of firms from one industry. In addition Minasian's correlation coefficients show that only 30-51% of variations in productivity are explained by differences in research spending. Nevertheless the conclusions are impressive particularly with regard to the lagged nature of the enquiry.

It would seem from these and other studies[56] that the relationship

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[56] Z. Griliches, 'Hybrid Corn: an Exploration in the Economics of Technological Change', Econometrica, (1957); E. Mansfield, 'Intra Firm Rates of Diffusion of an Innovation', Review of Economics and Statistics, (1963), 'Technical Change and the Rate of Imitation', Econometrica, (1961), 'The Speed of Response of Firms to New Techniques', Q.J.E., (1963), 'Industrial R & D Expenditures: Determinants, Prospects and

between R & D, innovation and technical change at the micro-level is fairly significant. The remainder of this chapter will be devoted to reconciliation of the apparent contradiction between the results at the micro- and those at the macro-level. The ensuing discussion will be rather general but will, I think, provide some grounds for the reinstatement of R & D as an important factor of production, especially at the regional level.

4. An Institutional Explanation of the Role of Research and Development

To begin with we should expect the impact of what is conventionally called basic research to be different both in extent and time-span from applied research and development. To this extent it is closer to the output of education insofar as basic research contributes to a span of knowledge concerning the general environment rather than to the debugging of any particular process or product. In particular we should expect funds allocated to basic R & D to have a relatively long pay-back period and a relatively high level of risk attached, in the commercial sense. It is not surprising, therefore, that firms devote only a small fraction of their R & D efforts to basic research. This has led Nelson,[57] for example, to argue that more public funds should be allocated to basic R & D since marginal social returns are greater than marginal private returns, and that steps should be taken to ensure that the resultant output of knowledge is efficiently distributed. However,

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56 (cont).
Relations to Size of Firm and Inventive Output', J.P.E., (1964). These studies of Mansfield emphasise the role of "expected profitability" as a determinant of investment in research and innovation by the firm; although see Griliches, 'Comment of Mansfield', op.cit.

57 R. Nelson, 'The Simple Economics of Basic Scientific Research', J.P.E., (1959).

this type of argument is conditional upon cost factors and clearly where large amounts of public funds are already being spent on basic research it does not follow directly that an economy is underinvesting in basic research.

It is important to recognise that resources committed to basic research will be subject to the same economic laws as those committed to investment in any other type of capital good. Thus after a certain point the marginal returns will fall and the marginal costs associated with an increase of such investment will rise. Clearly there must exist at any moment of time a point at which we can say that basic research spending has reached an optimal position, although in practice it would be extremely difficult to specify this position exactly. Some of the factors influencing this are as follows:

<u>On the supply side</u>:

(a) The quantity of educated manpower required to produce research output of a given quality.

(b) The existing stock of knowledge.

(c) The extent to which the capital equipment required becomes increasingly sophisticated and costly.

(d) The extent to which increased expenditure on research results in proportionately greater wasted effort. That is, in other words, the level and movement of the risk premium associated with investment in research.

<u>On the demand side</u>:

(e) The quantity and efficiency of distributional facilities necessary to tabulate, store, retrieve and distribute research results.

(f) The extent to which new knowledge is readily translatable into more efficient production of goods and services.

(g) The corresponding rates of return on other aspects of public spending.

(h) The notional social returns associated with the pursuit of knowledge for its own sake.

Evidently this optimum will change (although not necessarily increase) over time, often as a result of advances in past research. For example, the invention of the computer has meant that complicated experiments can now be carried out which at one time would have been extremely costly because of the calculation effort involved. And improvements in the educational system may lead to a greater quality and/or quantity of research manpower. Conversely the increasing sophistication of machinery necessary to carry out modern scientific experiments may lower the optimum. In addition the pattern of costs and benefits will at any point of time vary in different scientific disciplines. The high costs associated with current research in elementary particle physics are not paralleled by similar costs in, say, organic chemistry.

Without going into this discussion in detail two points emerge. Firstly, this whole area is one of considerable complexity and, secondly, it is extremely difficult to assess what point on the 'basic research curve' any economy happens to be at a particular point in time. Certainly it is not at all obvious that industrialised countries are under-investing in basic research. In the case of Great Britain there is a certain amount of indirect evidence to the contrary. Thus one recent Government White Paper makes the point that present increases in public spending on basic research (around 15% per annum) cannot continue at this rate, while during my own interviews it became apparent that business men are becoming increasingly unable to cope with the volume of trade and research literature sent to them. Moreover, the recent upsurge of interest in the efficiency of information systems would seem to suggest that the results of research are becoming increasingly difficult to assimilate. Quite clearly, therefore, it is possible to push investment in basic research too far.

How much of this analysis is relevant to applied R & D? Qualitatively, it would appear, applied R & D is quite a different animal. Whereas basic research is carried on in order to increase our knowledge and understanding of the scientific environment - and therefore plays a very small part in industrial research - applied R & D is devoted to using scientific and technological knowledge to produce commercially successful products within a strictly limited time horizon. Nevertheless, knowledge is still produced (and used) the difference lying in the fact that this knowledge is now embodied in the entrepreneur's product or the process required to make the product, and consequently becomes to a rather greater extent the private property of the firm. Moreover the motivations behind such investments will be those connected with the pursuit of entrepreneurial profit rather than curiosity regarding the environment. Presumably, nevertheless, it is still possible to speak in terms of an optimal level of R & D investment for the firm in terms of the usual marginal equalities used by capital theory but (possibly) with a higher risk premium to take account of greater uncertainty. Equally, a rational entrepreneurial policy is likely to give rise to a selection of research projects which maximises the present value of the future flow of returns. Clearly such investment appraisal would have to take into account not only all possible research projects but also other necessary forms of capital spending. A word of caution should be made here. Strictly speaking R & D as measured may be of two types, the first, mentioned above, consisting of short term research projects, while the second would account for those elements of technological 'back-up' necessary for the production of a given range of products. The latter type of R & D should more correctly be regarded as an overhead cost since it is an integral part of the productive process. Here again, however, no hard and fast line can be drawn, and very often it will be difficult to distinguish between the two types.

As in the case of basic research there are a number of factors which condition the optimum level of R & D investment. These will be on the supply side:

(a) The overhead costs of an efficient R & D department.
(b) The marginal capital costs for a series of relevant research projects.
(c) The supply of skilled manpower.
(d) The costs involved in obtaining access to relevant outside knowledge (e.g. information services, attendance at technical conferences, etc.).

On the demand side the important factor will be the relevant rate of return on this investment taking into account the risk element. Now just as in the case of basic research the optimum position depends upon time and the particular scientific discipline involved, so in the case of industrial R & D the optimum position will depend upon time and the particular industry in question, defining industry for the moment quite narrowly. Thus an industry which is close to technologically determined frontiers (like aircraft instrumentation or computers) will require by its very nature greater R & D facilities than one (like simple laboratory instrumentation or desk calculating machines) which is not. Similarly an industry which is closely related to a particular scientific discipline (like electronics) will require more extensive R & D facilities than an industry (like textiles) which is not. Again it is likely that an industry which is related to more than one basic scientific discipline may require more extensive R & D facilities than one which is related to only one. Finally, a lot may depend upon the nature of the 'science-base' since some industries (like computers) will require to invest in R & D on a much bigger scale than others (like electronic instrumentation), simply because the optimum scale for an efficient R & D programme will vary with the nature of the relevant scientific discipline.

Clearly for any industry this optimum will vary over time. Nor is it difficult to see how this could happen. For example, an industry based on a particular discipline would begin to place less emphasis upon R & D as the output of relevant knowledge from basic research in that discipline began to fall. This could easily happen where, after a certain point has been reached, marginal costs of research are greater than marginal returns (as in the case of the transistorised radio industry where, now that the technology has become widely spread, possibilities for improved products via more research have been significantly lessened). Conversely as new fields of excellence are opened up certain industries may find it necessary to increase their scales of research spending and competition may begin to take more the form of technical sophistication rather than traditional cost reduction. The important point, however, is that at any point in time there is a certain optimum level of research spending necessary for any industry and that this level is at least partially technologically given to the industry. For the firm research is largely a determined quantity.

A certain amount of evidence exists to support this hypothesis, although the support is circumstantial. Thus Freeman[58] in his investigations into research and development in the electronics capital goods industry categorises various 'threshold levels' of R & D capacity below which no individual firm is able to compete without eventually being driven out of the market. According to Freeman, what is important is not the level of R & D expenditure per se but that level beyond an initially determined absolute level, the level being determined by the relative sophistication of the science-base. In computers this threshold is high (c. £2-4 million), whilst in the manufacture of radio communications receivers it is fairly low (2. £40,000 - £75,000). In fact Freeman is mainly concerned with advocating rationalisation of firms into bigger units and with stressing the essentially international character of much of contemporary technological production. Nevertheless his conclusions do have a certain significance.

Secondly, Brozen[59] in explaining the quite substantial differences in

[58] C. Freeman, 'Research and Development in Electronic Capital Goods', N.I.E.R., (1965), No.34.
[59] Y. Brozen, 'R & D Differences...', op.cit.

research spending amongst United States industrial groups over the years 1951-60 places a lot of emphasis upon the quality of the science base. Thus, "with a good base in theory and a large heritage of information, experiments may be run cheaply with paper and pencil. Theoretical principles and prior knowledge can guide applied research and development workers to high pay-off, low-cost projects. With this help, much will be invested in R & D..."[60] Again Brozen is mainly concerned with a critique of the hypotheses associated with Schumpeter, Galbraith and Villard; viz. that monopolistic or oligopolistic industries tend to innovate more rapidly than competitive ones and correspondingly tend to carry out more R & D. He shows in fact that differences in competitive structure explain only 9% of inter-industry differences in R & D. The remainder, he suggests, may be explained by the differential quality of the science-base, the relative reliance upon R & D in supplier industries, the valuelessness of 'second-best' and, finally, demand factors. The important point, however, is that the "differences in research and development spending among different industries are very largely the result of the differences <u>in opportunity</u> for profitable investment in R & D".[61]

Finally, Mansfield[62] found in a study of the chemicals, petroleum, drugs, glass and steel industries, the actual level of R & D expenditures for the firm in each industry was a function of past expenditure, past profitability and how much it was necessary to catch up on desired levels of spending. Each firm seemed to envisage some natural level of research spending which would be the optimum level at that point in

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60 Ibid.
61 Ibid. (My underlining).
62 E. Mansfield, 'Industrial Research...', op.cit., chapter 2.

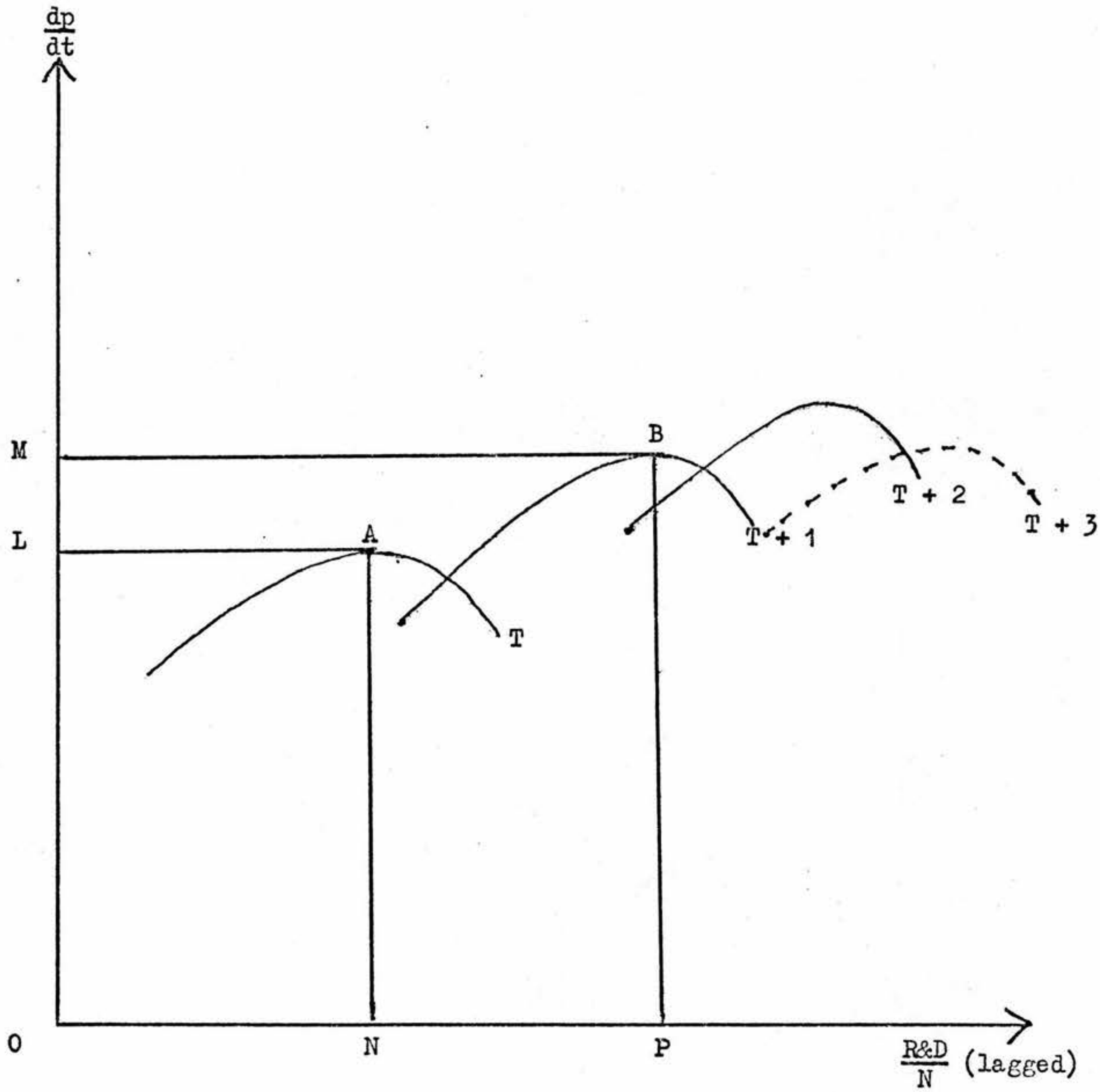
time. Nevertheless not all firms would be spending at the desired level.

Clearly, despite the fact that the general level of research spending may be given to the industry it is still possible for firms to vary substantially in their R & D inputs with respect to a notional optimality. The diagram overleaf illustrates the point.

Consider any industry in time period T. We should expect that in this time period there will be a certain level of technology and, by extension, research spending necessary for efficient production, A; but not all firms will be at this point. At points below A investment in research will yield increasing returns while at points beyond A decreasing returns will set in. R & D expenditures are corrected for firm size to allow for the fact that, as certain studies have shown, size of firm seems to have an influence on innovative output where levels of research spending are held constant. Consider now a movement to time period T + 1. By this time technology will have changed (in this case advanced) and we shall assume that its complexity is such that an increase of R & D expenditure, NP, results in an improvement in future productivity growth, LM, where firms are investing at the optimum level, B. In this case higher rates of productivity growth are possible which were outwith entrepreneurs' production possibility curves in previous states of knowledge. The level of technology may have changed, for example, as a result of the output of relevant basic research in past periods.

Clearly, however, not all firms may be in a position to invest at

FIGURE 1



Let $\frac{dp}{dt}$ = Rate of change of productivity

R&D = R & D expenditure (lagged)

N = A measure of the size of the firm

position B. Movements for curve T to curve T + 1 will depend upon how efficiently new states of knowledge are made available to the industry and, correspondingly, how active entrepreneurs are in seeking out such knowledge. They will depend upon age structure of existing capital stock which will embody (partially) previous technology. Other relevant determinants are managerial aptitudes, elasticity of supply of technical manpower, demand factors and so on. Also at 'new technology' levels firms need not invest at the short run optimum. Differential rates of discounting, access to investable funds, managerial policies, etc. will result in considerable variation in R & D investment amongst firms which will be reflected in differential rates of future productivity growth.

Thus it is perfectly possible to interpret the results of Mansfield, Minasian, et alas the logical consequence of firms varying in their research spending along the technologically given research curves outlined in Figure 1, whilst at the same time regarding industrial research spending as a largely determined phenomenon, determined as we have seen by past output of basic research, industrial structure, long-run shifts in the pattern of demand, etc. Looked at in this light while it is clearly very important for the firm to invest as close to its optimum position as possible there are many reasons why it may be neither able nor willing to do this. Conversely industrial R & D investment need have very little impact on industrial productivity growth.

The above analysis should in no sense be regarded as a rigorous theoretical treatment and indeed dangerously approaches tautology when examined closely since its relevance depends firstly upon how we define the product (i.e. it must fulfil similar economic needs over time) and secondly upon whether it is possible to speak meaningfully of discrete time periods at which discrete 'levels' of technology exist uniquely for that product. Nevertheless it does have certain strengths. For example, it is not in conflict with the fact that other factors may affect productivity growth. These can quite easily be built into the model. In addition it does go some way to resolving the conflict arising between the micro- and macro-studies discussed above. Finally it does have some, admittedly indirect, support in the literature.

5. Summary and Conclusions

This chapter has consisted of a review of certain aspects of the R & D-innovation process couched in terms of the economic and social pay-off to investment in innovative activity. Sections 2 and 3 depend heavily on an interpretation of a number of theoretical and empirical studies which have been carried on in this field in recent years, studies which although extremely valuable in themselves demonstrate quite clearly that we are a long way from a complete comprehension of the subtle and complex relationships that exist between investment in scientific and technological activity and the socio-economic context in which this investment takes place. To some extent this is only to be expected since this area of enquiry has only recently begun to be tackled systematically. In addition, however, difficulties occur because of a lack of adequate data which can be used to test hypotheses.

In section 2 it has been pointed out that while it is not possible at this stage to come to definitive conclusions, the existing evidence appears to show that investment in inventive and innovative activity (as measured by R & D statistics) is a poor explanatory factor of economic growth at the macro-level, compared to other factors. From the argument of section 3, on the other hand, it would appear that at the intra-industry level differences in R & D spending among firms is causally related to differences in firm performance, so that for certain industries at least R & D expenditures are an important part of the productive process and serve to ensure the firm's long run survival. In section 4 a first order explanation of this apparent contradiction is attempted. This rests on a fairly detailed discussion of the economics of the R & D process which leads to the tentative hypothesis that at any point in time there will be a certain level of necessary R & D expenditure which is by and large datum to the industry, but that firms within that industry will vary in their R & D spending about that normal level. This normal level is essentially a long run concept and will vary from industry to industry depending fundamentally upon the relevance and complexity of particular technologies. On the other hand since there are a variety of reasons why any particular firm may be either unable or unwilling to invest at this (optimal) level in the short run[63] it is to be expected that those firms which invest closer to this level will have better performance records.

Fundamental to this analysis are the following particular functions or roles of R & D investment.

(a) R & D as a Conventional Input

It should be noticed that the industrial research curves in Figure 1

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[63] Indeed the typical firm may not know what this level is, due to the inherent uncertainties in R & D investment.

need not take the form presented. New industries based on significant scientific break-throughs (such as, for example, the transistor) might show large productivity gains resulting from relatively little R & D input, while it is quite possible to envisage cases where new technology levels might require increased R & D investment but which at the same time produce lower rates of productivity growth. This would occur, for example, when a new (high R & D) product replaces an old (low R & D) product. The implication is that in recent years, over much of manufacturing industry, demand has shifted in favour of just these products. But their production requires research and development of the 'de-bugging' and 'testing' variety. In the absence of facilities for this the product could not be produced. And in this guise R & D expenditure becomes merely more overhead input in the production process.

(b) R & D as a Vehicle for Competition

As Hamberg has pointed out, a lot of R & D investment is carried out in order to differentiate products from competitors. The theory is that in science-based industries price competition is less important than competition in terms of 'quality'. Thus the range of possible qualities of goods may be so great that it is not meaningful to gauge the success of a firm on the basis of conventional micro-economic calculus. Put another way, the demand schedules of individual firms are constantly altering as a result of their own, and their competitors', development activities. Competition is carried on through research and development into ways in which products may be marginally improved. Under such conditions it is quite conceivable that the rate of obsolescence will increase in any product field and the corresponding rate of return on industry R & D to fall. On the other hand for any one firm to cut back on such R & D investment would be tantamount to giving up the manufacture of the product since this firm's product would become obsolete that much more quickly. The entrepreneur is constrained to run faster in order to stand still. To some extent, of course, the emergence of oligopolies might prevent this sequence, but even in this case international competition or 'demand-creation' might perpetuate high levels of R & D investment.

The importance of the R & D process when viewed from this angle does seem to have a certain significance from the point of regional economic development. Thus to the extent that the R & D process is inefficiently carried out because of locational factors, the long run growth of the region may suffer, not because R & D and growth are uniquely linked, but because under a competitive framework of production and distribution the region whose R & D effort suffers may find it increasingly difficult to compete on equal terms with other regions more favourably placed; particularly important here are the advantages that accrue to firms situated close to important research centres of excellence. A full articulation of this aspect of the problem is presented in the following chapter.

CHAPTER III

THE REGIONAL EFFECTS OF SCIENTIFIC CONCENTRATIONS

1. Introduction

This chapter will attempt to show that there are *a priori* grounds for believing that there are factors operating which inhibit the growth of science-based production at the regional level. For many industries technological advance, even in the short run, has become a very important influence on a firm's competitive performance and consequently decision-making at the plant level is increasingly dictated by technological factors. Among these factors are the scientific and technological capacities possessed by the scientific infrastructure - i.e. the network of public and semi-public institutions whose interests focus on R & D, higher education in science and technology, information gathering and distribution, and technological extension services to industry - and, more specifically, the ease with which these capacities can be used by industry.

While a closer association between industry and the scientific infrastructure may produce gains at the national level in terms of economic growth, this thesis is more concerned with its implications for the competitive position of firms, especially those firms in specific regions. Thus to the extent that a region is disproportionately underrepresented in terms of a scientific infrastructure and to the extent that distance between the scientific infrastructure and industry has a deleterious impact upon the effective use of this technology source, then firms in that region will be at a competitive disadvantage compared with firms in regions not so underrepresented. In general we should expect smaller firms to suffer a worse disadvantage because of their relative inability to support internal R & D capacities.

In regions with this characteristic there would be two immediate results, other things being equal.

(i) Firms would experience higher costs than those in other regions.

(ii) New firms would be discouraged from moving into the region.

Following the discussion in Chapter I it is suggested that these impacts would have a negative effect upon economic growth potential in the region, especially if, as seems to be the case, science-based industries are those experiencing fastest growth.

Section 2 examines evidence with respect to geographical 'clustering' of centres of scientific and technological excellence, and the industrial implications of this. A certain amount of evidence exists to support the hypothesis that scientific institutions and techno/industrial complexes tend to concentrate their activities regionally, although this evidence is somewhat limited. Section 3 expresses the additional costs experienced by firms, as a result of their distance from the scientific infrastructure, in more rigorous terms, qualifying the analysis from the point of view of lack of awareness of new technologies, use of inferior technologies, differential scientific receptivity of firms, and the differential experiences of large and small firms. Section 4 goes on to present a preliminary articulation of the types of relationships which we should expect to exist between industry and the scientific infrastructure, how important these relationships are and to what extent they are influenced by locational factors. To some extent this discussion anticipates conclusions reached as a result of the empirical work described in Chapters V and VI.

2. The Regional Incidence of Scientific Activity

What evidence exists to substantiate the hypothesis that scientific/ R & D activity tends to cluster geographically? Although the evidence on this is rather limited such studies that do exist show that the scientific infrastructure does have a tendency to concentrate itself into fairly well defined geographical locations. There is also evidence to suggest that the same pattern occurs with respect to techno/ industrial complexes - i.e. complexes of non-profit research institutions, including universities, technical colleges and government research and development establishments on the one hand and science-based manufacturing activity on the other - although the quantitative evidence on this is at present somewhat limited. A detailed discussion of the types of inter-relationships existing and their significance in terms of regional parameters is reserved for the subsequent sections of this chapter.

The clearest case is that of the United States of America where Cahn and Parthasarathi[1] point out that the "human and financial resources involved in the national effort in R & D - currently (1966) involving some 15% of the annual budget - are most unevenly distributed on a geographical basis over the country and... this distortion has, in consequence produced an imbalance in professional opportunities, which in turn has produced a further imbalance in the original distribution..."[2]

[1] A.H. Cahn and A. Parthasarathi, '<u>The Impact of a Government-Sponsored University Research Laboratory on the Local R & D Economy</u>', M.I.T. Occasional Paper, 12 January 1967.
[2] <u>Ibid.</u>, pages 1 and 2.

Thus in 1965 one-third of U.S. scientific and technological manpower were employed by the five leading metropolitan complexes which in addition held 58% of the prime R & D contracts awarded by the Department of Defense. Cahn and Parthasarathi go on to state that in the same year "some 45% of N.A.S.A.'s[3] R & D budget of $4.5 billion was spent in the single state of California. In fact over the period 1961-65, California received on the average 38.5% of all federal R & D funds, while the five Midwest States of Illinois, Wisconsin, Ohio, Indiana and Michigan together received only 6%. Or to put it more strikingly, the 'top' 25 states received in 1963 96.8% of all federal allocations for R & D, while the remaining 3.2% was divided between the 'bottom' 25."[4]

This process has not, of course, been confined to the scientific infrastructure itself but has had far-reaching effects on the local industrial economy and consequently upon regional economic growth. In the United States the two most striking examples of this are the growth of highly specialised 'R & D complexes' in the Greater Boston area and in certain areas of California[5] both of which have benefitted substantially from flows of government-sponsored research to these areas. Indeed one commentator maintains that the scientific and engineering manpower pool built up in the Greater Boston area has "done more to revitalise the Northeast (of the U.S.) than anyone would have guessed 15-20 years ago".[6] These regional benefits appear to have accrued largely as a result of government funding of basic and applied research

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[3] The National Aeronautics and Space Agency.

[4] Cahn and Parthasarathi, op.cit., p.2.

[5] D. Shimshoni, 'Aspects of Scientific Entrepreneurship', Ph.D. thesis, Harvard University, Cambridge, Mass., May 1966. See p.6.

[6] M.M. Wyatt, 'Where to Build a Research Lab', Industrial Research, (March 1962), p.27.

to institutions both within and without the scientific infrastructure - i.e. both to publicly owned research laboratories which may or may not subcontract development contracts out to local industry, as well as directly to private industry itself. Shimshoni concludes that "Government expenditure has had an overwhelming impact on new company formation because of government induced demand and government investment for technology. In the Boston area, about one half of the firms surveyed had more than one third of sales, during their first two years (of operation), directly to government or to prime contractors. For about one third of the companies, government sales amounted to two thirds of their markets".[7]

On a lesser scale but possibly equally important for future industrial developments in the United States is the phenomenon of the 'Research Park'. These can best be described as rather specialised industrial estates catering specifically for science-based and research-orientated industry. They are very often sited near universities reflecting the growing confluence of interests between university and industry. The universities can supply a range of specialised skills, knowledge and facilities while industry can supply employment opportunities for graduates, provide avenues through which university personnel can try out ideas commercially and act as a breeding ground for new spin-off companies. Indeed Browne maintains that "it may be that the most significant influence upon the success or failure of a research park is the proximity to, and the interaction with, nearby universities."[8]

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[7] D. Shimshoni, op.cit., p.6.
[8] T.B. Browne, 'The Changing Research Parks', Industrial Research, (May 1966), p.41.

There are now more than 30 university linked research parks in the U.S.[9]

A recent study of the scientific infrastructure in Czechoslovakia shows much the same tendency for R & D resources to be located primarily in certain regions. Müller and Nejedlý[10] examine the regional distribution of R & D activity in Czechoslovakia concluding that there are large regional inequalities as measured by data on scientific and technological manpower. 49.2% of all R & D university-graduated manpower is concentrated in Central Bohemia while a further 27% are employed in two other administrative centres (Brno and Bratislava). The remainder are dispersed throughout the further eight regions considered in the analysis. These inequalities are only slightly modified when 'pure scientists' are excluded.[11] The authors go on to perform a simple statistical analysis in which they test the hypothesis that regional differences are caused by the differing economic characteristics of the regions. Using data on production, capital assets and employment as regional economic indicators they obtain non-significant values for the correlation coefficients, but using numbers of university faculties and numbers of university students as indicators of the regional resources committed to education they obtain high and significant values for r . Thus the evidence suggests that R & D centres tend to be sited close to the 'traditional focuses' of science

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[9] Ibid. The same edition of Industrial Research lists a total of 101 such parks in the United States and Canada.

[10] K. Müller and R. Nejedlý, 'Regional Distribution of Research and Development', to be published in Research Policy and Planning, 1971.

[11] That is done by excluding scientists who work in institutes controlled by the Czech Academy of Sciences. This was done in order to ascertain the distribution of specifically industrial R & D capacity. See ibid., p.8 et seq.

and technology - the universities, which in Czechoslovkia are located mainly in the regions of central administration - but tend not to be attracted towards areas of high economic activity.

Anticipating the criticism that a rough analysis of this kind - i.e. correlating general economic indicators with R & D activity regionally - ignores differential scientific receptivity[12] amongst the regions, Müller and Nejedlý examine the relationship between the production levels of specific science-based industries and R & D effort. The analysis is again conducted cross-sectionally over eleven regions and six different science-based industries are studied. The resultant correlation coefficients show a much better fit and in two of the six industries - inorganic chemicals and pharmaceuticals - the coefficients are high and significant. Nevertheless Müller and Nejedlý conclude that industrial activity and research activity are not linked geographically in any specific way.

While this analysis does not altogether agree with U.S. experience it is clear that great care should be taken over its interpretation. The relationship between science and production is not one that can easily be picked up by statistical means and, as I argued in Chapter II[13] a lot depends upon the relevance of particular technologies to particular types of production. Clearly it is necessary to have information on the technological distribution of these global R & D figures and the degree to which R & D spending in each technological area has reached

[12] i.e. the industrial structures in certain regions may be such that there is a relatively small science-base and therefore less need for R & D activity. See note 13 below.

[13] For a fuller discussion see Chapter II, page 42 et seq.

an optimum level with respect to the industrial sectors examined before passing judgement on the influence of industrial activity on regional R & D spending. Thus a situation in which R & D investment had reached an optimum level in those technologies relevant to the inorganic chemicals and pharmaceuticals industries but in which there was under-investment in those technologies relevant to the other four industries analysed could produce correlation coefficients of the values reached by Müller and Nejedlý which would not necessarily be inconsistent with the hypothesis that industrial activity is influenced by regional investment in R & D.

Moreover the centrally planned nature of the Czechoslovak economy has an important bearing on the issue since a lot will depend upon the perceived need for industry and research to cooperate closely. To the extent that science-based industry performs little 'in-house' R & D and to the extent that planners do not recognise the advantages to be obtained from close contact between factory and laboratory, the results arrived at above may simply reflect inefficiencies in R & D resource allocation. Shimshoni[14] points out that one of the primary factors in the development of an R & D/industrial complex is the tendency for firms to 'spin-off' from local laboratories, started by entrepreneurs who were previously laboratory employees and often supported for long periods by contracts, technology and know-how from the parent laboratory. One would not expect this tendency to show itself to the same extent in Czechoslovakia.

Finally, of course, the analysis is to some extent vitiated by the nature of the data which is at best only a rough approximation to a

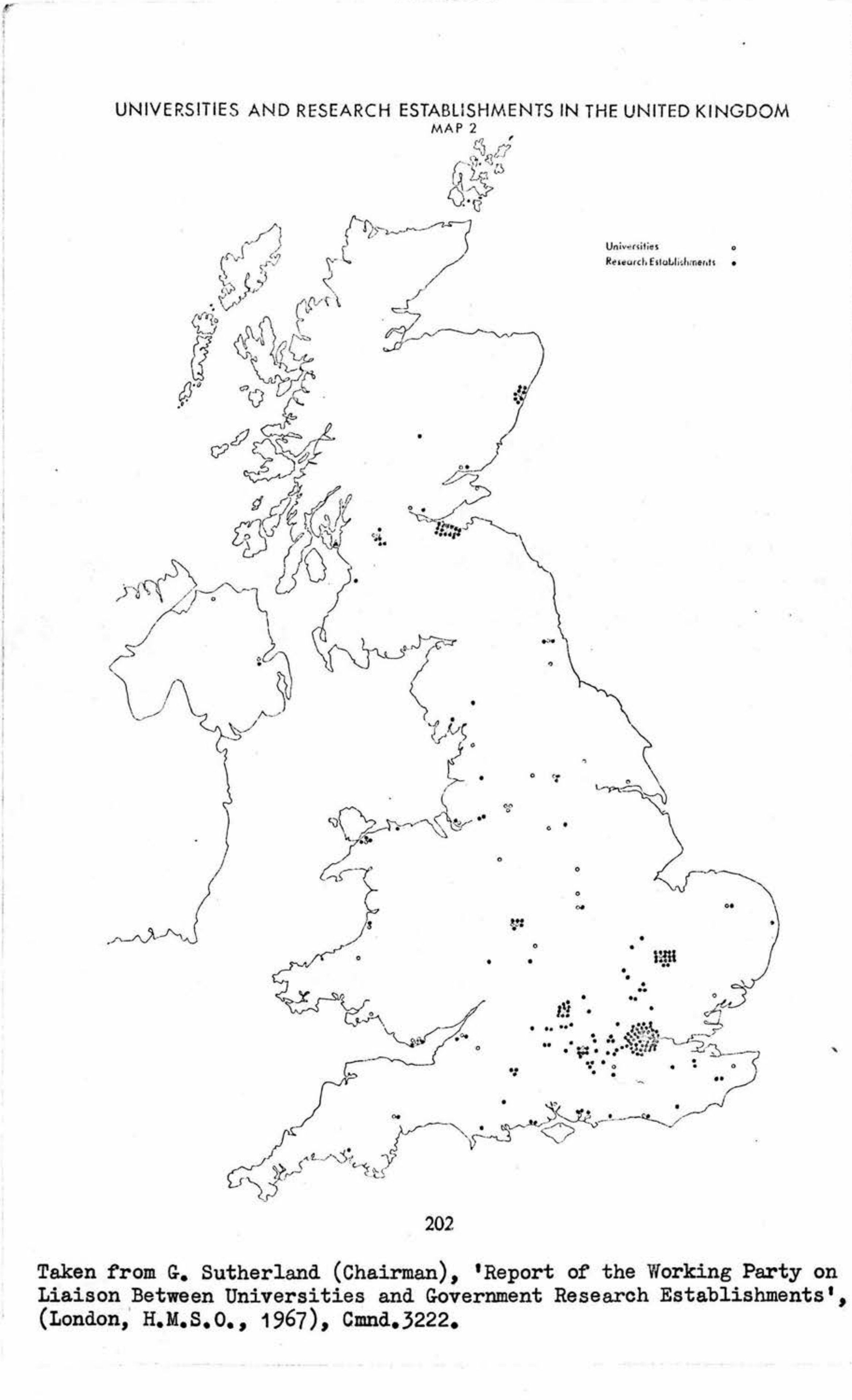
[14] D. Shimshoni, op.cit., chapter I.

true measure of innovative activity. It could very well be, for example, that a region ostensibly low in R & D manpower is in fact producing a very much higher (relatively speaking) output of research because of a variety of factors such as, say, a high capital/labour ratio or a low labour/output ratio determined in turn by the nature of the technologies involved. Again the R & D effort in the 'high' regions may be carried on in a small number of top-heavy inefficient institutions whilst in the 'low' regions there may be the same number of institutions but operating at higher levels of efficiency because of advantages associated with smaller size. This is not to suggest size and inefficiency are necessarily highly correlated but merely to point out that the value of the R & D effort will depend upon a variety of influences and basing correlation analyses on one particular measure of it is bound to open the way for bias.

Clearly we should require a lot more information before we could say that in Czechoslovakia there is no tendency for industry and research to locate themselves in the same geographical areas. What is interesting and rather more significant, however, is the regional distribution of scientific activity by itself and it will be shown below that there are a number of possible causes of this phenomenon.

The British experience again produces similar patterns. Figure 1 portrays the geographical distribution of government research stations and universities in the U.K. (1966) and it can be seen that in the case of the former there are fairly marked clustering patterns with high densities in the Greater London area, Oxfordshire, Northants, Edinburgh and Aberdeen. Indeed the concentration in the south east of England is

FIGURE 1



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Taken from G. Sutherland (Chairman), 'Report of the Working Party on Liaison Between Universities and Government Research Establishments', (London, H.M.S.O., 1967), Cmnd.3222.

pronounced. Of the 200 or so stations 153, or 76%, are located within 3½ hours train journey from London (1960 speeds) and 143, or 71%, are located south-east of a line drawn between the Bristol Channel and the Wash. Of the 32 (16%) Scottish stations, 9 are M.R.C. stations, 12 are A.R.C. stations[15] and 5 others are directly concerned with the fishing industry. The remainder are the Naval Reconstruction Research Establishment, the National Engineering Laboratory, the Road Research Laboratory, the Unit of Grouse and Moorland Ecology, the Royal Observatory and the Royal Botanic Gardens. Of these six stations one would expect only the first three to have substantial direct relevance to a modern science-based industrial sector in Scotland. Nor would one expect the A.R.C. stations to be of much significance in this regard and the same probably holds true with respect to the M.R.C. stations with the rider that there may be advantages in close contact between this set of stations and the electronics industry due to the fact that much of present day advance in medical research involves the use of electronics instrumentation. At the same time it is very probable that the nature of government R & D effort in Scotland reflects the importance of the agriculture and fisheries industries. In fact three out of the eight stations located in Aberdeen, an important fishing centre, are directly concerned with research into problems connected with fishing.

These geographical concentrations do not hold true with respect to universities but it is interesting to note that of the 47 grant-aided

[15] G. Sutherland (chairman), '<u>Report of the Working Party on Liaison Between Universities and Government Research Establishments</u>', (London, H.M.S.O., 1967), Cmnd.3222. See Appendix F, p.196. M.R.C. = Medical Research Council; A.R.C. = Agricultural Research Council.

industrial research associations only one is located in Scotland although two others have sub-stations in Scotland.[16] Many of these research associations are located in areas where there is a concentration of the relevant industries (e.g. British Ceramic R.A., Stoke-on-Trent; The Cutlery and Allied Trades R.A., Sheffield), reflecting the original aims of the D.S.I.R.[17] which was to ensure a close connection between research and industrial production by way of setting up these institutions. Clearly these locational regularities are no accident.

Finally, a further aspect of these general relationships is evidenced with respect to two constituent sectors of the scientific infrastructure, the university and the government research establishment. Not only does it appear that the formal and informal links between these two sets of institutions are considerable, there is also evidence that the degree of contact is substantially influenced by regional factors.

In 1965 a Working Party was set up by the Council for Science Policy in the U.K. to "consider the question of liaison between universities and government scientific research establishments".[18] Its remit was to assess the existing situation and to "examine whether (the facilities possessed by establishments) might be made more accessible for

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[16] Ministry of Technology, 'Technical Services for Industry', (London, 1967). This volume gives details of all outside research bodies and the services they provide for industry.

[17] The Department of Scientific and Industrial Research. This body was closed down in 1965 and most of its functions taken over by the Ministry of Technology.

[18] G. Sutherland, op.cit., p.1. The following discussion is largely based upon this document.

educational and research purposes at universities, and whether the specialised knowledge of workers in research and development establishments might play a greater part in higher education". It is clear, however, from an examination of the Working Party's report that it envisaged the advantages accruing from such contact to be much wider than just this, insofar as substantial economies would, in its view, result from closer liaison.

These advantages are:

(a) Since much of the work performed is common to both sets of institutions close cooperation avoids duplication of research and wasteful competition for scarce manpower, facilities, etc. In particular the cooperative use of expensive capital equipment (for example, computers) would economise on public money.

(b) Both sets of institutions are repositories of much technical knowledge and the pooling of this knowledge would considerably improve the quality of training and research.

(c) In addition close links would benefit both sets of institutions at a more informal - but equally important - level. On the university side there would be a greater appreciation of the contribution that the academic scientist can make to the solution of vital national problems and to industry. In addition it would gear the training of new scientists towards the types of problems considered important nationally and industrially, and consequently would facilitate the recruitment of suitably skilled manpower to government establishments. On the establishment side there would be a quicker appreciation of the "practical significances of advances in pure science"[19] made within the

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[19] Ibid., p.3.

universities. The Working Party goes on to point out that university research laboratories are "often livelier than government research laboratories" because of the continuous influx of fresh young minds. Each year there is the stimulus that about 30% of the youngest age-group is replaced by new-comers, whereas government laboratories, apart from those going through a rapid phase of expansion, recruit annually a very limited number of new young staff... (so that)... a wider policy of giving fixed-term fellowships, or short appointments, to a fraction of the younger scientists employed at government laboratories and a more frequent involvement of a few of the permanent staff in the teaching and research training of the next generation of scientists could be very beneficial in this respect".[20] It would seem, therefore, that the Working Party believed that government establishments stood to gain just as much from closer liaison as the universities and it is interesting to note that, from all evidence obtained during the enquiry, the establishments were rather more positive in their welcome for a closer relationship.[21]

Written and oral evidence was obtained from all government employers of scientists, and all universities and colleges of advanced technology. This evidence summarised the existing state of affairs and the views of each institution as to how the situation could be improved.

As an illustration of the type and extent of contact involved it is perhaps simplest to take the case of the national laboratories controlled by the Ministry of Technology since their experiences seem broadly

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[20] Ibid., p.3, 4.
[21] Ibid., p.56.

to parallel those of other classes of government establishment. These Mintech laboratories have extra-mural research and teaching agreements, consultancy arrangements, research fellowships and arrangements for the employment of vacation students. University staff serve as members of establishment steering committees and also on specialist sub-committees concerned with specific aspects of the overall research programme. Directors of establishments work closely with university heads of departments in placing research grants with universities and they are also empowered to receive individual research students to work, say, towards a Ph.D. degree at no cost to the university.

For example, the National Physical Laboratory (N.P.L.) receives regularly a number of requests to help in teaching specialist courses at universities. Courses have been arranged on chemical and engineering standards, mechanical engineering, ship control and stability (University of London), on temperature measurement (University of Surrey), on mathematics (Brunel University). Also the N.P.L. have arranged a number of joint research projects with universities, e.g. the development of a Michelson stellar interferometer (Sussex), the measurement of spectroscopic line profiles (Oxford), the development of a laser interferometer for seismological purposes (Cambridge). The same general pattern of relationships seems to exist with respect to the government departmental establishments - particularly the defence departments - with other bodies such as the United Kingdom Atomic Energy Authority (U.K.A.E.A.) establishments and with Research Council Stations.[22] The U.K.A.E.A., for example, had 140 consultants from 30 universities, several members of their staff have joint posts with

[22] For a rough breakdown of government research establishments see Chapter VI, pp 148 and 149.

universities and there exist a number of joint research projects.[23] The Research Council stations, in addition to the normal links, actually have research units operating 'in-house' within the universities and in these cases contacts are particularly close and, it seems, mutually beneficial.

Not only, however, are the relationships between universities and government research establishments far-reaching, it becomes quite clear that there is a definite regional pattern involved. The Working Party received evidence from 40 universities and colleges of advanced technology relating to the nature of the links existing and to the particular establishments with which these links are maintained. Although little attempt was made to analyse the regional importance of its findings, the detailed evidence presented in Appendix C[24] has enabled me to perform a rough quantitative analysis of the position existing at the time (1967). Out of a total of 38 universities, 26 (nearly 70%) had close links with establishments in the same geographical area (<u>very roughly</u> with establishments sited within 50 miles of the campus). Of these 26 only seven (18% of the total) had equally important links outside their own areas. Two (5%) appeared to have contacts which were definitely non-regional, seven (18%) appeared to have little contact of any kind and three (8%) did not give sufficient information upon which a judgement could be made. Thus despite the rough nature of the analysis it is clear that many more universities had closer relations with neighbouring establishments than vice-versa.

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[23] G. Sutherland (chairman), <u>op.cit</u>., p.9.
[24] <u>Ibid</u>., pp.96-186.

Typical of the former class of university is the University of Edinburgh which has the following links with research stations in and around Edinburgh:

(a) Five Medical Research Council Units, (M.R.C.). The honorary directors of three of these are full time members of university staff while the remaining two have staff with honorary senior lecturer status. Each of these units operates within the University itself.

(b) Seven Agricultural Research Council Units (A.R.C.). Each of these is closely involved with university departments in research and teaching.

(c) There is also close contact with the Freshwater Fisheries Laboratory (Pitlochry), the Scottish Marine Biological Association's Oceanographic Laboratory (Edinburgh) and the Royal Observatory (Edinburgh). The only local station with which there is no contact is the Naval Reconstruction Research Establishment (Dunfermline). It is interesting to note that none of the sample of firms interviewed in the course of this study had links with this particular laboratory.

(d) The Regional Computer Centre set up 'in-house' in the University has promoted close links with local establishments.

Similar close links are evidenced with respect to the University of Birmingham and the Royal Radar Establishment (R.R.E.) Malvern, the University of Exeter and the U.K.A.E.A. station at Winfrith, Dorset, and the University of Strathclyde and the National Engineering Laboratory (N.E.L.), East Kilbride. Finally a number of universities mentioned in their evidence that they would like government research stations to be situated nearby. Thus the University of Newcastle maintained that it "would make much more use of the staff of research establishments if they were situated anywhere near (the University), but a list of such establishments contains very few places north of Leeds and still in England".[25] Of course, this general regional pattern should not be overstated. There were a number of cases (particularly with respect to U.K.A.E.A. stations) of links maintained over quite a wide geographical distance (Aberdeen University and Aldermaston, for example), but the evidence clearly shows that such links were the exception rather than the rule.

3. Theoretical Analysis

The previous section produced a certain amount of evidence to the effect that scientific activity tends to concentrate itself regionally. There is also a certain amount of more limited evidence which might lead to the supposition that centres of scientific and technological excellence may exert a locational pull on those industries whose products are related to the appropriate 'science-base' of these centres, although for reasons which become clear below we should not expect this phenomenon to reveal itself explicitly. This section and the following one will attempt to provide a rationale for this process, a rationale already demonstrated tentatively with respect to the mutual advantages associated with close linkages between different sectors of the scientific infrastructure.

The focal point of this thesis is the importance of science-based production in regional development, since it is precisely this type of production which exhibits fastest economic growth.[26] In Chapter II it

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[25] *Ibid.*, p.151.
[26] See Chapter IV.

was shown that while innovative activity could not be directly linked to growth performance at the macro-level, firms within particular industries did benefit from increased R & D spending within certain broad limits. In consequence if there are factors at the regional level which inhibit the effective translation of new techniques into production, then it is reasonable to suppose that these factors would inhibit potential economic development in certain regions. What might these factors be? It is suggested that one important variable may be the ready access to new technologies - and the important source of potential markets - represented by the scientific infrastructure. Moreover, the operative phrase is 'ready access', which implies that time and distance are pertinent variables.

Shimshoni[27] mentions a number of reasons why nearness to research laboratories has a significant influence on the performance of new science-based firms. These are:

(a) A reduction in the costs of acquiring market knowledge.

(b) The importance of rapid communications for the selling of technologically-intensive products since applications engineering often rêquires continuous technical interchange between buyer and seller.

(c) Serendipity - a term denoting the probability of diffusion of ideas, techniques, etc. through chance encounters with knowledgeable individuals. This probability will be greater the larger the number of skills and interests represented in a given (small) geographical area. This concept clearly includes the type of informal technical interchange which can occur when people with mutually relevant interests meet socially.

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[27] D. Shimshoni, op.cit., pages 6, 7.

(d) Ready access to specific research results which may be of relevance for production.[28]

(e) The availability of a pool of highly skilled manpower which may, for a variety of reasons (cultural and social), be reluctant to move away from the district and may, therefore, be anxious to take jobs in local industry.

(f) The availability of risk capital from a financial community with understanding of the problems and risks of scientific entrepreneurship.

(a) and (b) are peculiarly related to the role of the scientific infrastructure as an important market but one with a key extra dimension, i.e. the necessity for close user/supplier contacts when selling a sophisticated capital good. In addition there are two reasons which Shimshoni does not mention but which are clearly important. These are:

(g) Ready access to centralised facilities such as computing and library services which it may be beyond the cost of individual entrepreneurs to afford on a sufficient scale.

(h) Possibilities for consulting key individuals from the scientific infrastructure with respect to particular technologies. A special case is that of secondment for a certain length of time.

It is apparent that centralised inputs of this kind will play an important role in the production of science-based commodities. Indeed what has been demonstrated by Shimshoni for the new small firm will, by extension, hold true for the larger, more established firm although as will be demonstrated below we should expect the impact to be less

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[28] Shimshoni finds that this is a relatively unimportant factor from his interviews with businessmen.

strong. Going back, then, to the locational pull of the scientific infrastructure and discussing it in economic terms, it seems reasonable to hypothesise that the important variable is the cost of acquiring relevant technologies which increases in direct proportion as the time required to obtain the technologies. Thus, for example, where close technical interchange is necessary between buyer and seller both of which are located at some distance from each other, periodic visits will be necessary and the cost involved will be equal to the direct cost of travel plus the foregone production of the engineer(s) in question.[29] Evidently the firm located close to the market will be at a comparative advantage and two firms operating in different regions, one close to a number of laboratories and the other some distance away, but producing the same product under the same economic environment would exhibit different cost functions.

More rigorously, let the relevant production function be

$$O = f(x_1, x_2 \ldots\ldots\ldots x_n; \; x_t)$$

where $x_1, x_2 \ldots\ldots\ldots x_n$ are the conventional factors of production (labour, capital, etc.), x_t represents technological input, O represents output. Then the appropriate cost function is represented by

$$C = p_1 x_1 + p_2 x_2 + \ldots\ldots + p_n x_n + p_t x_t$$

where $p_1, p_2 \ldots\ldots p_n$ are conventional factor prices, p_t is the price of technological input and C is total costs. Assuming that firms

[29] It can be argued that effective communications may be conducted by telephone or by letter. However, several firms mentioned to me that technical interchange of this kind was much more effectively carried on through a person-to-person discussion. Often, for example, an applications engineer will have to inspect prototypes 'on site' and/or engage in detailed discussion with the buyer using blue-prints, manuals, etc. In these cases contact by telephone is relatively inefficient.

attempt to maximise profits - i.e. minimise costs for given levels of output - and that prices and quantities of all other factors remain the same, then for a given level of output but differing prices of technology the total cost differential is represented by

$$\triangle C = x_t (p_t'' - p_t')$$

where p'', p' represents the prices of technology to the firm located close to and the firm located at some distance from the scientific infrastructure respectively. In the above analysis technology has been treated as a single factor of production but it is possible to generalise to take into account the different 'elements' of technology required for production. In this case the cost differential is given by

$$\triangle C = x_{t1} (p_{t1}'' - p_{t1}') + x_{t2} (p_{t2}'' - p_{t2}') + \ldots\ldots + x_{tn} (p_{tn}'' - p_{tn}')$$

where there are n elements of technological input. Evidently for operational purposes it may be necessary to separate out these elements since price differentials due to regional factors will be different in each case. The overall hypothesis is, therefore, that <u>ceteris paribus</u> any advantage which one firm has over another in terms of ready access to technological inputs, can be expressed in terms of the above cost differential. There are, however, a number of points which require clarification.

(1) To begin with technology is conventionally regarded as a factor which <u>shifts</u> production possibility curves rather than producing movements along any particular curve. This is related to the fact that whereas conventional inputs can be regarded as contributing directly to production at a given moment in time, the impact of technology is seen,

correctly, as influencing production over a wider time perspective and is therefore included as an exogenous variable in most production functions. Salter,[30] for example, views technology as being embodied in capital stock and consequently as being beyond the control of the firm in the short run. New technology will be introduced via new capital equipment only when the discounted stream of future benefits exceeds costs (including normal profits) by an amount greater than foregone net benefits using the old equipment. Where technology is regarded as being disembodied it is still viewed as the result of cumulative investments in innovation during past periods (Minasian,[31] for example, achieves his most significant results on technical change in the chemical industry using a distributed lag model of R & D activity). Nevertheless, it is still possible conceptually to regard each firm - in the above example - as using essentially the same technology, whether embodied or disembodied, but having different long run costs because of unequal access to external technology. Of course, enormous problems would present themselves were empirical measurements of such cost differentials to be attempted.[32]

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[30] W.E.G. Salter, 'Productivity and Technical Change', (Cambridge University Press, 1966).

[31] J.R. Minasian, 'The Economics of Research and Development', in 'The Rate and Direction of Inventive Activity', (N.B.E.R., Princeton University Press, 1962).

[32] Normally, of course, a distinction is made between the 'long run' and the 'very long run', the distinction being that in the long run the entrepreneur varies his fixed capital while in the very long run radical changes in technology add a further dimension to the entrepreneur's production possibilities. While this may be true in the case of very radical innovations, like the jet engine, I would argue that for science-based industry in general technological change takes place over much shorter time horizons, either through new capital stock (Salter) or through new disembodied technologies using the same - and/or new - capital stock. The important point is that technological change involves costs and that, from the point of view of an analysis which tries to separate out one particular element of these costs in a general sense, the distinctions between 'short run', 'long run', and 'very long run' are academic.

(2) In the second place, it is possible that differential access to external technology might result in different <u>quality of product</u> with respect to these firms. Thus the firm situated away from the scientific infrastructure may very well substitute an inferior technology resulting in a product of poorer quality - assuming the original technology to be optimal. Here again this produces no conceptual difficulties if we regard quality differentials of product as being functionally related to price differentials of the most appropriate technology.[33] Thus, if

$$k = g(p_t) \quad \text{where } k = \text{product quality, we have}$$

$$\Delta C = x_t \left[g''(p_t) - g'(pt) \right]$$

and if there are net differences due to <u>actual</u> payments for technology the expression becomes

$$\Delta C = pt''x_t'' - p_t'xt' + xt''(g'' - g')$$

where x_t'', x_t' are respectively the optimal and suboptimal technologies. An alternative scheme might be to regard each firm as having a different <u>probability</u> of acquiring the correct technology. This takes into account the fact that not all firms will be <u>aware</u> of the optimum set of technological inputs because of differential locations with respect to technology sources. In this case the appropriate production function is

$$0 = f\left[x_1, x_2 \ldots\ldots x_n, P(x_t) \right]$$

where $P(x_t)$ = the probability of the optimum technology being utilised. The cost differential is now given by

$$\Delta C = p_t''P''(x_t) - p_t'P'(x_t)$$

using the same nomenclature as before. This is clearly analogous to

[33] i.e. assuming that the entrepreneur will at the margin trade off inferior quality of product against the relatively higher cost of obtaining external technologies. This does not seem to be an unreasonable assumption.

the previous case since firms with low $P(x_t)$ will tend on the average to utilise inferior technologies and produce inferior products.[34] In fact, under similar market conditions

$$p_t''P''(x_t) - p_t'P'(x_t) = p_t''x_t'' - p_t'x_t' + x_t''(g'' - g').$$

The advantage of couching the analysis in probability terms is that it highlights the fact that, in a world where technological change is occurring so rapidly, perfect knowledge of technological alternatives must be the exception rather than the rule, and it is implied that firms located close to centres of scientific excellence will be at a comparative advantage.

Notice also that there are scale factors present. Thus the relative advantages to a firm located near one particular laboratory may in general be small, since it is unlikely that this laboratory by itself will be capable of supplying more than a small number of the various 'elements' of technology required for production. It is suggested that there exists for most industries an essential discontinuity between technology and production such that an appropriate 'technology package' for a given product will contain inputs from a variety of scientific and engineering disciplines. For example, the production of electronic instruments requires inputs from metallurgy, semi-conductor technology,

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[34] Another result may be that lack of awareness of new technological opportunities will reduce the scope for product diversification and this could be true even where no new investment is required. For example, a plant producing polyethylene can very simply be converted to the production of ethylene oxide and in a situation of under-utilisation of capacity the knowledge that this can be done (and also, of course, of how it is done) would be extremely valuable for the firm. I am grateful to Charles Cooper of the Science Policy Research Unit for pointing this out to me.

paint technology, spring technology and a variety of other disciplines and sub-disciplines. Clearly the advantages will be greatest for the firm situated close to a number of laboratories, constituting a complex of relevant disciplines, and we should, therefore, expect $P(x_t)$ to be directly related to the number of laboratories within the geographical environment of the firm. The relative success of university-centred research parks in the United States provides some justification for this hypothesis.

(3) We should expect size of firm to have a significant influence on differential cost structures. Economies of scale have not been taken into account in the specification of the production function but it is evident that the larger firm may, for a variety of reasons, be able to offset disadvantages associated with distance from technology sources. Leaving aside questions of economies of scale and market imperfections, one important advantage which the large firm possesses is the ability to rely very much more upon 'in-house' technological activity since the overhead costs of an R & D department can be covered more easily. This will be particularly important where new technologies are developed in secret which give the firm a technical lead over competitors, but it may also have significance insofar as it obviates the necessity to go outside the firm for certain technological elements, such as computer services. Other things being equal, therefore, it would appear that the smaller firm stands to gain more (or lose less) from close proximity to the scientific infrastructure although again this will vary from industry to industry[35] since for some products a relatively small firm may be able to support a viable R & D department.

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[35] See C. Freeman, Chapter II, note 58, who places a lot of emphasis upon inter-industry differences in the minimum necessary R & D capacity.

(4) Similarly, following the discussion in Chapter II, it would appear that the economic significance of such technology costs will vary from industry to industry. For example, industries with a high scientific receptivity would be affected more than industries whose technology is widely known and understood. Also industries relying on a small number of specific well-defined technologies would be affected less than industries which depend upon a wide spectrum of technical disciplines.

(5), Finally, abstracting from industrial differences of the types mentioned above, it is not possible to state how important technological factors are in relation to other factors known to be important in industrial location. For example, nearness to supplies of a key raw material or closeness to large markets of a non-technical nature might outweigh the disadvantages of distance from sources of technical knowledge. Thus, although we have seen that there is a certain amount of evidence which <u>suggests</u> the significance of the technological factor it is still to be shown that its <u>relative</u> significance is sufficiently important to justify, for example, policy action.

This analysis is not intended as a rigorous treatment of the costs of technology. Quite clearly it could be refined extensively, as we have seen, to include market imperfections, inter-industry differences, scale effects, etc.;[36] and it would have to be extended in this fashion if a viable statistical analysis of differential cost structures due to

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[36] One point, for example, which has not been discussed explicitly is that there may very well exist economies of scale in communication, such that the effort involved in acquiring a particular technology may produce benefits, not only with respect to that technology, but also in terms of new technological opportunities not hitherto recognised.

technological factors were to be attempted. However, since that is not the purpose of this thesis it is sufficient to state the nature of the problem. This has been done mathematically for clarity of exposition.

4. Some Further Elaboration

In the last section it was tentatively hypothesised that firms located at some distance from concentrations of scientific and technological activity would experience greater costs of acquiring appropriate technologies than firms situated close to such concentrations; and a delineation was made of the types of technology input that may be pertinent.[37] In this section I shall articulate these technological factors in more detail and at the same time attempt to specify what sorts of advantages accrue to the firm as a result of close direct links with the scientific infrastructure. This discussion will not be systematic in the sense that it will consist largely of an exploration, in a priori terms,[38] of the nature and value of links which we should expect to encounter. In fact one of the objectives of the empirical work, described in Chapters V and VI, has been to establish a more concrete perspective of this aspect of the problem. Although the scientific infrastructure is clearly much more broadly based, I shall confine my remarks at this stage predominantly to academic bodies - i.e. university and technical colleges - and to government research laboratories,[39] since these seem to be the most important generators of new technologies.

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[37] See the beginning of section 3.

[38] Needless to say, I am indebted heavily to the authors already cited in this chapter for the valuable insights which they have produced. In addition some of the findings from my own empirical work are anticipated here (but not specified) for the sake of completeness.

[39] Other components of the scientific infrastructure, e.g. research associations and professional institutes, are discussed in Chapter VI.

(a) Academic Bodies

An important regional impact of a new scientific institution such as a university, is the spin-off of specialised R & D and/or production companies from the parent body.[40] These are essentially started off through trained manpower perceiving a demand for particular technology and/or products based on their own work, leaving the university and setting up on their own. The markets for these products may be the parent university itself, other universities, other scientific institutions, science-based industry, or any combination of these. Such companies often tend to set up in the immediate environment of the parent body, even where there is no 'research park' of the kind discussed in section 2, and it is interesting to speculate on the reasons for this.

One important factor might very well be the natural reluctance of skilled personnel to leave an area where they have built up strong social ties both personally and as regards their families (schools, housing, etc.). Inertia of this kind may be more powerful in the case of personnel who have had their initial training in the corresponding institution. Secondly the new entrepreneur may wish to remain in the same area because of easy access to former colleagues who have specialised insights into particular aspects of the relevant technologies. In fact it is very likely that such colleagues will act as consultants to the new firms.

Thirdly closeness to the parent university may be desirable insofar as

[40] See Cahn, Parthasarathi and Shimshoni, op.cit. Both studies produce impressive evidence testifying to the importance of this phenomenon.

there are a number of specialised facilities available, uniquely related to the technologies of the new firm. Indeed we should expect this to be the case since the new product has, almost by definition, originated from R & D conducted within the parent laboratory. Let us suppose, for example, that a new type of semi-conductor has been developed in a university research laboratory and that a number of engineers, previously laboratory employees, have set up a new company to produce this component commercially because they envisage that it has a viable market potential. It may very well be the case that certain testing and standardisation facilities are required which are directly relevant to the new product - and may even be specific to that product - but are housed within the laboratory and are too expensive for the new small company to invest in. Clearly there will be considerable locational advantages in siting the new factory close to these facilities. In addition it will normally be the case that moving from a laboratory prototype to a commercial model will involve changes in design and/or raw materials and at this stage the 'de-bugging' of the product may require the use of expensive apparatus and/or technical expertise which is only available in the parent laboratory. Evidently extensive discussion may be necessary between the parent and the firm and there will be, in consequence, advantages in geographical proximity.

Fourthly, the research in the university laboratory, upon which the new product has been based, will normally be part of an on-going programme which may very well provide advances in technology relevant to that product. In this guise the parent laboratory can be seen as a continuous source of new technology giving the spin-off company a competitive edge over its rivals. There may also be advantages to the university. For example, the 'problems' experienced by the new company may be useful vehicles for the training of students who may be required to carry through and solve simple research problems as part of their degree work.

Fifthly, more general facilities (e.g. computing and library facilities) will be available free or at low cost to the new company. Finally, the role of the parent as a market or, possibly more importantly, as a testing ground for a wider market, should not be overlooked.

What has been discussed above relates to the spin-off company which has by definition close links with the parent laboratory. Evidently, however, there is another class of 'non-spin-off' company for which the advantages of close relationships with a university department may be just as beneficial. Such a company may have commenced manufacture in close physical proximation to a university for a variety of reasons. It may have been started up by a man who had received his initial training in the area, who had gone to work with a larger corporation elsewhere but had subsequently returned to the original area for personal reasons, or because he anticipated some sort of benefit from the work being carried on in the university laboratory. This company would be essentially entrepreneurial but could not be described as 'spin-off' in the above sense.

Another type of company might be a sales affiliate to a company located elsewhere which has decided to go into manufacturing (or partial manufacturing) of the relevant products. A special case is that of the sales affiliate to an overseas company which may commence production for a variety of reasons. Thus differential tariff policies on final as opposed to intermediate goods, or the necessity to adapt a product to render it suitable for the home market may create an incentive in favour of setting up manufacturing (and possibly R & D operations) within the host economy. A number of such companies were included in my sample[41] and it became clear that these gradually began to diversify their product range into areas divorced from original company interest. One factor influencing locational choice might be the existence of a university laboratory possessing skills relevant to the company's activities. A possibly more important incentive might be the existence of regional development policies designed to encourage new firms into an area - e.g. tax holidays, grants, low rent factory space, etc.

Now although these non-spin-off companies may not initially experience such close technological links with the laboratory - excepting those companies which have moved into an area to take advantage of specific technological capacities extant in that area - it is to be expected that they will become aware of the technologies and facilities available, and it would be surprising if some of these were not exploited. In this way closer links will be forged of the kinds mentioned above such that ideas, techniques and insights developed in the laboratory will become integrated into the production activities of the firms. Furthermore, the firms may see new commercial opportunities in particular 'in-house' developments and may shift their product structures into activities which are more in line with these techniques, often by offering facilities for university personnel within the firm. Shimshoni places stress on this mechanism, maintaining that technology "is often transferred most effectively by the movement of a man into an

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[41] See Chapter V.

existing company rather than starting his own. New technical companies have been particularly effective 'hosts' for such movements".[42, 43]

(b) Government Research Laboratories

We should expect the relationships here to follow similar lines to those with academic bodies.[44] Thus the government laboratory may spin off new companies and act as a technology source to other companies sited in its own area. Library and information services, computing facilities, more specialised facilities such as test, calibration and precision engineering facilities, skilled manpower, etc., will each act as technology 'generators' or 'diffusers' and could play a significant role in technological developments in the local R & D economy.

However, it is convenient to mention three possible differences. Firstly, to the extent that work related to national security is being performed in government laboratories the technology potential for the local economy will be reduced. A priori we should expect this to be the case with respect to laboratories administered by departments of defence. Secondly, we might expect the government laboratory to play a more positive role in the fostering of local innovative capacities, since while the university's predominant task is to educate and train students, the government laboratory is predominantly orientated towards problems of national (including industrial) importance and this

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[42] D. Shimshoni, op.cit., page 3.
[43] There is also similar evidence relating to British experience. See, for example, B.E. Launder and G.A. Webster, 'University Research and the Considerations Affecting its Commercial Exploitation', (London, T.D.C., January 1969).
[44] This is implicitly recognised by the Sutherland Committee's Report insofar as it emphasises the growing confluence of research interests between universities and government research laboratories. See D. Sutherland (chairman), op.cit.

has clear implications for private industry. Thus, for example, the National Engineering Laboratory (N.E.L.) has recently undertaken to introduce specific engineering design facilities using computer technology with a view to acting as a centre which can help small local firms to improve the engineering design of their products.[45]

This point is also exemplified by the third important difference between government laboratories and academic bodies, viz their differential importance with regard to the marketing of technologically intensive products. Besides their importance to industry as actual markets for sophisticated equipment, government laboratories act as intermediaries between buyer and seller insofar as they are linked with - and often controlled by - government departments. These departments are in effect a large and significant public sector market and to the extent that related laboratories are performing research appropriate to this market, it may be very necessary for firms within this field to maintain close links with the laboratory. Thus a naval research establishment performing research into improved forms of navigational equipment may demonstrate the need for particular types of navigational aids (such as, for example, specialised radar devices), or a transport laboratory performing research into improved road safety may come up with a scheme which requires the commercial production of special instruments (such as, for example, fog warning apparatus).

In each of these cases, while it may occasionally be the practice of

[45] J. Fowler, 'Research in Scotland - 1', Scotland, (October 1968), 49-53. This is only one of a number of examples of the N.E.L. taking an active role in stimulating the local industrial environment. The laboratory views this as one of its basic tasks.

the laboratory to manufacture a batch of the relevant products itself, in general such activity would take it outside its recognised sphere of competence as primarily a research organisation. Moreover, it will not normally possess the facilities for large-scale production. In such cases it is the practice for these laboratories to place contracts with industry but to ensure that the necessary standards and specifications are adhered to, and it would appear that there are obvious advantages in close cooperation between the laboratory and industry at an early stage. From the point of view of the laboratory, firms with relevant technological expertise may be enormously helpful in attacking particular developmental problems or in pointing out that if a certain type of product is eventually required, then initial development should follow certain specific paths.

For example, the firm may recommend the use of a certain type of raw material because it is in plentiful supply or because it possesses technical characteristics which give the final product greater commercial viability. In this way it can guide R & D into areas such that the raw material in question can be effectively used. From the point of view of the firm, close contact of this kind will keep it cognisant of the latest developments in particular areas, and may very well lead to future production contracts since the firm's engineers will have been closely involved at all stages of the R & D process, and will doubtless be at an advantage when tenders are put out to offer. Even closer links are sometimes established where firms actually perform R & D themselves on a development contract basis. More generally such contact will fulfil the role of keeping the firm in touch with particular market trends.

It will be pointed out in Chapter VI that this particular 'marketing' link between firms and the scientific infrastructure was very much under-anticipated at the inception of the study. But as it progressed it became evident that technological interchange of this type was a significant aspect of contact with respect to the sample of firms examined.

(c) <u>Some Further Aspects</u>

Two final points should be made. Firstly, re-emphasising the discussion in section 2 on the discontinuity between technology and production, it is clear that the advantages associated with close links between science and industry will be very much greater where a firm can locate itself close to a <u>complex</u> of scientific institutions such that it will have access to a wider spectrum of technological inputs. Also to the extent to which scale factors of this type increase the number of firms (and industries) wishing to set up or expand production facilities in the region, we should expect to witness external economies within the industrial sector itself. For example, the development of a complex of companies manufacturing a variety of electronic components and sub-assemblies could lead to a parallel establishment of firms requiring these intermediate products for their own production. Firms of this type, manufacturing possibly on a larger scale for a more standard market, could well feel that technological improvements at the component level would improve their own production performances. Their establishment could, in turn, produce further backward linkages in terms of new intermediate product firms, linked on the one hand to the technology source represented by the scientific infrastructure and on the other to the firms requiring the existence of specialised component manufacturers. There is evidence that dynamic growth of this kind has taken place with respect to the electronics industry in the south-east of England.[46]

Finally, returning to the question of firm size, it should be pointed out that it is often the small technologically-intensive firm which is able to compete with the giants in certain areas. The advantages which the larger firm possesses in terms of marketing facilities, access to sources of finances, risk-taking, etc. are often those which accrue to the firm at the stage when the products and their associated technologies are already established. On the other hand American experience has shown that smaller firms, relying on close interchange with scientific laboratories and concentrating solely on a particular product, can make substantial inroads into a well-established market.[47] It is possible that measures designed to encourage the growth of such firms could play a significant role in fostering the industrial health of an under-developed region.

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[46] Although it has not been shown explicitly that the initial causal factor was the existence of a viable scientific infrastructure. See reference in note 1, Chapter IV.

[47] D. Shimshoni, <u>op.cit.</u>, pages 3-5. Shimshoni mentions this in connection with innovations in the process control and physical analytic sectors of the scientific instruments industry.

CHAPTER IV

THE SCOTTISH CASE

1. Introduction

This chapter relates the problem of regional scientific activity and its impact on regional development to the case of Scotland, as being an example of a relatively underdeveloped geographical sector within a larger national economy - that of the United Kingdom. Section 2 deals with the problem of Scottish underdevelopment, how it is defined and what are its causes, by way of an examination of the most important recent study of Scottish economy - that of the Toothill report[1] and by examination of further relevant studies and official published statistics. These sources show that the basic Scottish problem has been one of a deficient industrial structure insofar as Scottish industry has been over recent years (certainly since the second world war) disproportionately dominated by the relatively slow-growing traditional industrial sectors, and that despite a succession of government initiatives to deal with the situation, this basic structural deficiency has been remarkably persistent right up to the present day. Since, conversely, many of the fast-growing industries tend also to be science-based,[2] this gives an indication that there may be certain factors inhibiting the growth and

[1] J.N. Toothill (Chairman), 'Inquiry into the Scottish Economy - Report of a Committee appointed by the Scottish Council (Development and Industry', (Edinburgh, 1961).

[2] Although not all. Many of the new mass-production consumer goods and consumer durable industries, which located in the South-East of England and the Midlands, did so for reasons of close proximity to a large and affluent market. These cannot be described as directly science-based although it is arguable that the capital goods required for their production did benefit from technological advance.

performance of the science-based sector in Scotland, and equally it indicates that it may be worthwhile to enquire whether an important conditioning factor may be technological in character.

Section 3 attempts to assess Scottish industrial R & D activity in comparison to that of Great Britain by means of a first-order statistical analysis. The data on R & D in Scotland was supplied, on request, by the Scottish Office; the data for R & D in Great Britain and the data for other economic indicators were extracted from official published sources.[3] Despite the inadequacies of the statistics, it is clear that Scottish industrial R & D performance has been consistently poorer, and markedly poorer, than that of Great Britain. While this may have been due to differences in industrial structure, it is unlikely that this is the only cause. However, the Toothill Report places the blame squarely upon the shoulders of a backward industrial structure, and it is argued in Section 4 that (possibly as a consequence of this) the Committee of Enquiry's subsequent examination of the problem was not sufficiently rigorous. In particular it is argued that a closer examination of the relationship between the scientific infrastructure and manufacturing industry might have led to rather different policy recommendations but, at the very least, would have provided a better base and rationale for those policy recommendations that were made.

Finally Section 5 sets the stage for the empirical work described in the following chapters. Since Scottish industrial structure is unfavourable, particularly with respect to science-based industries, and since there is a heavy concentration of government research

[3] See references in Section 3.

laboratories in the south and east of England, it may well be that physical distance has an important influence on the flow of technical knowledge to firms in Scotland. This suggests the hypothesis that geographical distance affects the ease with which technological contact can be made and that this will be reflected in the extent of such contact actually made. Section 5 goes on to articulate this hypothesis in more detail and to describe the choice of the 'electronics' sector as being a suitable vehicle for testing it. A detailed discussion of the methodology adopted is reserved for Chapter V.

2. The Scottish Problem

It is difficult to assess accurately the extent of the underdevelopment problem in Scotland. The two best indicators are unemployment and industrial production, but an important causal factor stressed by both the Toothill Report[4] and McCrone[5] is industrial structure. To begin with unemployment has been consistently higher than the U.K. average since the first world war and this has persisted despite the relatively high levels of employment experienced by the country since the second world war. Unemployment averaged 3.1% of the insured working population between 1948 and 1960 compared to a U.K. average of 1.7%[6] and, while between 1959 and 1968 there seems to have been some slight improvement towards the end, the overall picture is very much the same. Table 1 shows that the corresponding percentages were 3.7% and 2.0% when averaged over this period. This process has had its counterpart in a persistently high level of net emigration from Scotland which seems to have increased

[4] J.N. Toothill, op.cit.
[5] G. McCrone, 'Scotland's Economic Progress, 1951-1960', (Allen & Unwin, 1965).
[6] J.N. Toothill, op.cit., p.17.

in the early sixties despite the optimism of the Toothill Report.[7]

TABLE 1

UNEMPLOYMENT

(Percentage of Insured Working Population)

	1959	1960	1961	1962	1963	1964	1965	1966	1967	1968	Average
Scotland	4.4	3.6	3.1	3.8	4.8	3.6	3.0	2.9	3.9	3.8	3.7
U.K.	2.3	1.7	1.6	2.1	2.6	1.7	1.5	1.6	2.5	2.5	2.0

Source: Regional Abstract of Statistics, (H.M.S.O., 1969).

It is true that this Scottish figure (3.7%) compares favourably with certain other U.K. regions - notably Ulster which has had an unemployment rate consistently double that of Scotland - and with other countries. Nevertheless the fact that this disproportionality has persisted despite a series of government iniatives[8] to correct it is widely recognised as symptomatic of a basic structural problem.

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[7] Unpublished data supplied by the Scottish Council.
[8] There have been a variety of these, taking mainly the form of provision of incentives designed to encourage industry to move into underdeveloped regions. Thus under the Distribution of Industry Acts (from 1945-1958) £5.8 million was made available as loans and grants to Scottish firms; some of this was specifically for new enterprises. Under the Local Employment Act (1960) £13.9 million was made available, mostly in the form of loans. Of this £11.3 million was for new enterprises. From 1945 to 1960 the Board of Trade financed the construction of 49 million square feet of factory building, mainly on 21 new industrial estates in Scotland. In all the Toothill Report estimates that £33.9 million was made available in the form of grants and loans to Scottish industry between 1945 and July 1961. See Toothill Report, op.cit., Appendix 38. The Regional Employment Premium is an example of a more recent measure.

Further evidence comes from an examination of industrial production. Between 1954 and 1959 industrial production rose by 13% in the U.K. compared to 3% in Scotland. The corresponding figures for Wales and Ulster are 13% and 17% respectively.[9] McCrone shows that this was paralleled by a relative decline in gross domestic output. From 1951 to 1960 as a proportion of the U.K. total this fell from 9.3% to 8.7%, while gross domestic product per head fell from 92% of the U.K. level to 88%.[10] There is some evidence that the relative situation may have improved somewhat in recent years but the overall picture bears out the evidence of the unemployment and net emigration data.

Why has this situation come about and why has it persisted in the teeth of government pressures and the increasing urban and industrial congestion in the south-east and Midlands of England? It is clear that the main problem is one of industrial structure and it is here that historical factors are important. During the 19th and the early part of the 20th century Scotland built up a considerable expertise in chemicals, heavy engineering and shipbuilding. Even during the inter-war years Scotland maintained a relatively leading position in marine engineering, boiler manufacture, locomotive building and structural engineering but according to Burns and Stalker[11] this was due not so much to the introduction of new techniques or products but more to the scale upon which production activities were carried on. Certainly one would expect the depression to have had a dampening effect upon the introduction of new techniques via investment and there was certainly

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[9] J.N. Toothill, op.cit., pages 20 and 21.

[10] G. McCrone, op.cit., page 120.

[11] T. Burns and G. Stalker, 'The Management of Innovation', (Tavistock, 1961), see page 45.

an absolute decline in these industries over the inter-war period, especially those catering largely for an export market which had suffered in the thirties due to the general contraction of international trade.

However, in the newer expanding industries which were beginning to take over Scotland was severely under-represented. Burns and Stalker make the point that in "electrical engineering, photography, motor cars, aircraft, rayon, wireless, telephones, plastics, pharmaceutical chemicals, non-ferrous metals and alloys... Scotland had by 1945 little or no share" and that it was largely due to this large-scale structural defect that the Scottish Council was set up in 1947 to encourage primarily the growth of precisely these modern types of industry.[12] Why had the necessary transformation not come about despite the fact that Scotland has had a distinguished record in a wide variety of industrial skills, especially in engineering? The Toothill Report after a careful examination of the problem gives three main reasons.

First of all the newer industries were geared more to <u>the requirements of large and growing home markets</u> than were the older industries which were located originally near specific sources of supply (coal and iron) and were comparatively heavily export orientated. The newer products tended either to be 'large-quantity, standard consumption goods' or 'small-quantity specialised capital goods'. For the former, closeness to a large market or at least a large centre of communications served the dual purpose of cutting distributional costs and keeping firms closely aware of changes in consumer demand, a very important

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[12] *Ibid*, page 45.

consideration in the 'low profit rate-high volume' type of activity. For the latter a very important part of the production effort required close technical interchange with the consumer both to ensure correct product specification and to build up personal relationships over a fairly long period. This leads on to the second reason which is basically the changing science-base of the new industries. Thus although Scotland was producing small-quantity specialised capital goods these were essentially different insofar as these were based upon the older heavy-engineering types of technology. The newer industries were derived from the developments in electrical engineering, electronics, telecommunications and chemicals which had taken place during the inter-war years and as a result of the war effort, and these had their counterpart in the development of industries (consumer goods, consumer durables, light capital goods) which were both different in type and less tied to traditional sources of supply. Burns and Stalker point out that specifically in industries (both capital goods and consumer goods) related to developments in electronics there were inherent advantages in closeness to the market,[13] and no doubt this held true with respect to other industries and technologies. In addition many of the newer mass market industries tended to rely heavily on firms supplying specialised tools, precision machinery and components, these firms tending to grow up around the main industrial centres largely because of communications factors.

These fundamental differences meant that "diversification on the part of the older firms was an inherently more difficult process since plant,

[13] Ibid, chapter 4. This was particularly important with respect to the government market which played a major role in the formative years of the post-war electronics industry.

machinery and production methods had to change radically in terms of (their) established technological background".[14] This was further exacerbated by <u>the impact of the depression</u> which led to excessive over capitalisation, falling demands and profits thus making the changeover that much more hazardous. In fact the Toothill Report maintains that many of the newer industries "did not originate so much from men well experienced in the older established industries as from men, mostly young who appreciated the significances of new technological developments and were able to assess their potential markets. Sometimes, but by no means invariably, they were those with the profoundest understanding of new technology; they were rarely the leaders of the older, established industries".[15]

These three factors then, the strong market orientation of the new industries, their different technological character and the impact of the depression together were mainly responsible for the structural problem facing Scotland after the second world war, according to the Toothill Report and there seems to be little reason to question their overall analysis although no doubt the process was rather more complex. Nevertheless, once the process had started, for whatever reason, the structural inbalance deepened and remained endemic. Analysing comparative industrial structures in Scotland and Great Britain using emplayment data from 1950-1958 the Toothill Report showed conclusively that the basic relative structure had remained the same[16] and that this was largely due to under-representation in the growing industries. In recent years the picture has not changed much. Table 2 shows that

[14] J.N. Toothill, <u>op.cit</u>., page 29.
[15] <u>Ibid</u>., page 33.
[16] <u>Ibid</u>., page 29. See also Appendix 2.

whereas in shipbuilding and marine engineering, and in textiles in Scotland in 1968 had 23.3% and 12.4% of U.K. employment levels respectively, in chemicals, vehicles and electricals the corresponding figures were 6.8%, 4.7% and 8.2% respectively.

TABLE 2

SCOTTISH/U.K. EMPLOYMENT RATIOS FOR SELECTED INDUSTRIES 1968

(Percentages)

Industrial Sector	Ratio
Ship-building and marine engineering	23.3
Textiles	12.4
Engineering and electricals	8.2
Chemicals	6.8
Vehicles	4.7
All manufacturing	8.3

Source: Abstract of Regional Statistics, (H.M.S.O., 1969).

These figures should be compared with the overall manufacturing industry ratio of 8.3%. Moreover there is evidence that an examination of trades within the broad industrial categories cited would reveal a greater Scottish concentration among the slow-growing industries. For example, from a rough count of the number of electronics establishments known to be operating in the U.K. in 1967, only around 50 (or 3%) were situated in Scotland.[17]

3. Scottish Research and Development Activity

In this section an attempt has been made to provide a rough quantitative assessment of the R & D effort in Scotland. Data on qualified R & D manpower (Q.S.E.) and expenditure in Scotland was supplied by the Scottish Office and the Ministry of Technology for the years 1962 and 1965. This was unpublished data derived initially from the Triennial surveys of scientific and engineering manpower in Great Britain[18] but since the expenditure data was estimated from the manpower data using national wage and capital per man figures there seemed little point in analysing the latter separately. In addition the data provided was broken down into the 2-digit Standard Industrial Trade categories for manufacturing industry which made it possible to analyse R & D performance taking into account relative industrial structure. The 1955 survey of R & D activities in British manufacturing industry[19] provides a global Scottish figure for all manpower working on R & D but using the Great Britain ratio of 'qualified' to 'total' R & D

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17 David Rayner Associates, 'The Eurolec Guide'. The count of electronics establishments ignores obvious factors such as relative size distribution and the fact that some of the establishments were purely sales offices. There is now some evidence that in more recent years this percentage has increased somewhat, but it is still well below the average for all U.K. industry. I am indebted to Mr. Ian Piper of E.R.A. for pointing this out to me.

18 (a) 'Scientific and Technological Manpower in Great Britain, 1962', (H.M.S.O., 1963), Cmnd 2146.
(b) 'Report on the 1965 Triennial Manpower Survey of Engineers, Technologists, Scientists and Technical Supporting Staff', (H.M.S.O., 1966), Cmnd.3103.

19 D.S.I.R., 'Estimates of Resources Devoted to Scientific and Engineering Research and Development in British Manufacturing Industry, 1955', (H.M.S.O., 1958.) See page 19.

manpower it is possible to generate an estimate of Scottish Q.S.E. employed in R & D during 1955/56. Clearly the assumption of constant proportionality is arbitrary since it implies overall a parallel level of technological sophistication if it is accepted that this ratio acts as a rough index of relative skill levels. On the other hand for the derived Scottish figure to be an underestimate of the true situation, Scottish R & D activity would have had to be relatively more skill intensive than the corresponding U.K. activity in the aggregate. And as this seems to be unlikely, it is reasonable to assume that the derived Scottish estimate is an upper limit estimate of the true situation. No industrial break-down is possible for this early period. Corresponding R & D data for the whole of Great Britain was provided by the sources already mentioned.[20]

Two measures of the R & D effort were used: (i) $^{RD}/_{E}$ - no. of qualified persons employed in R & D per 1,000 men employed. (ii) $^{RD}/_{O}$ - no. of qualified persons employed in R & D divided by an index of gross output. Employment data was taken from the relevant editions of the Ministry of Labour Gazette. Data on output was extracted from the Monthly Digest of Statistics (Great Britain) and the Scottish Digest of Statistics (Scotland). Clearly use of a manpower measure by itself would lead to misleading inferences since an apparent fall in research effort may simply be due to a decline in industrial activity - in this case relative decline as the aim is a comparison between Scotland and Great Britain. Thus deflating research manpower by raw employment and gross output makes it possible to trace relative

[20] See notes 18 and 19; also 'Scientific and Engineering Manpower in Great Britain', (H.M.S.O., 1956).

paths of R & D 'intensiveness' net of exogenous industrial movements. Deflating by gross output has the additional merit of providing a measure of how resources allocated to R & D have changed over time. However, it is important to note that the output figures are based upon those of the index of industrial production, so that the statistic $^{RD}/O$ may only be used to make spacial and temporal comparisons. As an absolute quantity in itself it is meaningless.

A further valuable statistic is $^{RD}/S$ (number of qualified R & D persons employed per qualified scientists) since this allows for industrial 'receptivity' to R & D. As pointed out in Chapter II, it is evident that certain industries are by their very nature more closely aligned to scientific activity than others, so that when making cross-industry comparisons it is instructive to allow for this. It seems reasonable to assume that an industry's scientific base is proportional to the number of scientists that it employs at least as a first approximation. From the point of view of a Scottish/U.K. comparison, data on $^{RD}/S$ would have helped to clear up one major difficulty which is discussed below; viz. differences in research effort as measured by $^{RD}/E$ and $^{RD}/O$ may still be caused by differences in trade structure <u>within each 2-digit category of industry</u>. Thus knowledge of the number of scientists operating in each group would give an indication of the overall technological base of that group and consequently would go some way towards assessing the extent to which inter-regional differences in research intensity (as measured by $^{RD}/E$, $^{RD}/O$) are due to differences in industrial structure at the 3-digit level. Unfortunately details of scientists in Scottish industry were not available so that a direct comparison of this kind was not possible.

Finally mention should be made of data deficiencies since in an analysis of this kind the main stumbling-block is a serious lack of adequate quantitative material. These deficiencies are mainly in coverage and size. By coverage I mean that figures for different years are not strictly comparable. For example, it is difficult to assess accurately trends in R & D effort over the period 1956-1965 because the earlier data refers to establishments employing at least 100 men, while the later data refers to establishments employing at least 11 men. Obviously a precise analysis becomes impossible at this point and the best that can be hoped for is an indication of the trends involved. By size I mean sheer quantity of data. Had there been, for example, adequate coverage for a greater number of years an extremely useful time series analysis could have been made.

With these reservations in mind the statistical picture is plain. Tables 3 and 4 show that for both measures used the research effort in Scottish manufacturing industry moved from under $^2/5$ of the British Total in 1956 to over $^1/2$ in 1962 and then declined to significantly under $^1/2$ in 1965. The turning point, of course, need not have been in 1962.

The differences over the first period in the rate of change of both increases is explained by the fact that output in Scotland was growing at a very much slower rate than in the rest of Great Britain (1.1% per annum in Scotland, 2.7% per annum in Great Britain), so that the evidence suggests a significant improvement in Scottish R & D data in the late 50's albeit from a very low level and this despite slow growth in industrial activity.

TABLE 3

QUALIFIED PERSONS EMPLOYED ON RESEARCH AND DEVELOPMENT

AS A PROPORTION OF TOTAL EMPLOYEES (THOUSANDS)($^{RD}/_{E}$)

		Scotland	Scotland/ Great Britain	Great Britain
Establishments	1956	1.414*	39.9%	3.548
employing 100	1959	-	-	4.465
or more	1962	2.713	55.3%**	4.908
Establishments employing 11 or more	1962	2.214	65.1%**	3.402
	1965	2.047	49.2%	4.162

* The 1956 figure for Scotland was calculated on the basis that the proportion of total to qualified workers on R & D was the same both for Scotland and the U.K. There is no data on qualified workers in Scotland at that date.

** These suggest that Scottish manufacturing industry spends relatively more of its R & D in small firms than is the case for the rest of G.B.

TABLE 4

QUALIFIED PERSONS EMPLOYED ON RESEARCH AND DEVELOPMENT

AS A PROPORTION OF GROSS OUTPUT* ($^{RD}/_{O}$)

		Scotland	Scotland/ Great Britain	Great Britain
Establishments	1956	7.742	37.7%	20.532
employing 100	1959	-	-	22.984
or more	1962	12.917	50.0%	24.865
Establishments employing 11 or more	1962	15.114	54.7%	27.612
	1965	12.038	43.3%	27.787

* See notes to Table 3.

However, even in 1962 the Scottish effort was extremely low and the decline to 1965 was pervasive. Table 5 presents a breakdown for specific industry groups according to the 1958 Standard Industrial Classification, showing that save for the 'metals' sector all industry groups in Scotland suffered a decline in research effort over the period 1962-65, whereas over the whole of Great Britain the trend is always upwards. And in only two sectors, 'chemicals' and 'electrics' was the relative discrepancy less than 6 percentage points per annum. Moreover, there was over this period very little difference in the overall growth rate of industrial output (Great Britain 3.9%/ann., Scotland 4.0%/ann.).

Further evidence for the differential regional input of scientists comes from a recent (unpublished) study of manpower requirements for the engineering industry.[21] This exercise was an attempt to relate skill structures in a particular sector of the engineering industry, agricultural machinery (except tractors), industrial engines, textile machinery, contractors plant and quarrying machinery, mechanical handling equipment, office machinery and other machinery, to size of firm by means of a cross-sectional least squares analysis. Since, however, there may be differences in skill structure with respect to regions the authors included a regional variable in their analysis.

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[21] Cowling, Dean, Pyatt and Wade, 'An Investigation of the Demand and Supply for Manpower in the Engineering Industries - a Pilot Study', (University of Warwick, 1969). I am grateful to the authors for permission to comment on this work, which is yet at an early stage of development.

TABLE 5

COMPARISON OF ESTABLISHMENTS EMPLOYING 11 OR MORE

BY INDUSTRY GROUP - SCOTLAND AND GREAT BRITAIN***

SCOTLAND	1962 $\frac{RD}{E}$	1965 $\frac{RD}{E}$	%/ann. change 1962-1965
Food, drink, tobacco	0.808	0.471	-13.90
Chemicals	11.111	11.032	-0.03
Metals	1.873	2.338	+8.28
Mechanical engineering and shipbuilding*	2.370	2.136	-3.30
Electrics	7.833	7.721	-0.48
Vehicles	1.302	0.935	-9.41
Textiles, leather & clothing	0.723	0.523	-9.21
Other**	1.090	0.763	-10.01
TOTAL	2.214	2.047	-2.51

GREAT BRITAIN	1962 $(\frac{RD}{E})$	1965 $(\frac{RD}{E})$	%/ann. change 1962-1965
Food, drink, tobacco	1.451	1.598	+3.38
Chemicals	13.980	15.947	+4.69
Metals	2.717	3.412	+8.53
Mech.engineering, ships*	1.766	2.361	+11.23
Electrics	10.481	11.981	+4.77
Vehicles	5.650	6.053	+2.38
Textiles, leather & clothing	0.943	1.093	+5.30
Other**	1.323	1.720	+9.99
TOTAL	3.402	4.162	+7.44

* Mechanical engineering and shipbuilding sector includes marine engineering and metals n.e.s.

** Includes ceramics, timber, furniture, paper and publishing.

*** Based upon figures supplied by Scottish Statistical Office.

Thus the general specification took the following form:

$$Y_i = Y_i\,(X_1;\ X_2;\ \ldots\ldots\ X_{11},\ U_i) \quad \text{where}$$

Y_i = the number of employees in the ith skill category expressed as a percentage of total employees

X_1 = the size of the establishment measured as total employees

$X_2 \ldots X_{11}$ = ten regional 'dummy' variables taking on the value 1 when the establishment is located in that region and 0 when it is from any other region

U = disturbance term.

The best fit was obtained from a double log specification. The eleven regions were the current (1967) economic planning regions. The base region was the Northern region and the coefficients on the regional variables represented deviations from the relationship between proportion of each skill category and size of establishment in the Northern region. For the category 'scientists and technologists' the results are interesting.

Thus, although regressing Y against X_1 by itself reveals that only about 20% of the variability in the proportion of scientists and technologists is explained by size, the inclusion of the regional variable considerably improves the explanatory power, indicating significant regional differences in proportions of scientists and technologists holding size constant. What is especially interesting is that all regional deviations were positive <u>with the exception of Scotland which was negative</u>. In addition the largest positive deviations were from the Southern, West Midlands and London/S.E. regions in that order. In fact an examination of the results reveals that as you move from 'North' to ' South' the proportion of scientists and technologists employed, holding size constant, increases. Since the analysis covers only one relatively small industrial grouping it seems reasonable to assume that these differences will also reflect differences in R & D inputs.

It would appear, therefore, that this is further tentative support for the thesis that Scotland is under-represented in terms of R & D inputs. In this case it may be that the regional effects simply reflect the fact that multiplant firms tend to focus their R & D activities in the South. Or, it may be that firms in the south spend relatively more per head on technological innovation. Either way, however, it reveals a disturbing imbalance of research activities amongst the different regions of the country.

4. The Analysis of the Toothill Report.[22]

The previous section has shown that on the basis of the limited data available Scottish industry has made a relatively poor showing in science and science-based activities. It was also demonstrated tentatively that there is a likelihood that differences in industrial structure cannot be held to be totally responsible for this state of affairs, since on the basis of the available statistics R & D effort *per employee* was lower in all sectors of Scottish manufacturing industry than in the corresponding sectors of G.B. industry in 1965 and there is additional evidence that the situation has deteriorated since 1962 despite marked improvement in Scottish industrial production over the period 1962-1965. When the R & D figures were deflated by output data

[22] J.N. Toothill, *op.cit.* For discussion of this see paras 21.18 - 21.32

much the same picture emerged. This to some extent contradicts the Toothill Report which concluded: "The question as to the adequacy of Scottish industry's performance is an employer of qualified research staff in comparison with industry in Great Britain cannot be put beyond doubt one way or the other. Such evidence as there is suggests that the different proportions are chiefly a reflection of the different industrial structures".[23]

The Report bases this conclusion on the fact that even within the recognised industrial classification, Scottish industry is weighted in favour of non-science-based sectors. Thus in 'vehicles' a disproportionately high effort is maintained in service stations and in railway rolling stock and locomotive manufacture, both industries with a low scientific receptivity. There was at the time only one motor vehicle manufacturer which accounted for practically all the R & D conducted in this sector. Correspondingly the one large aircraft manufacturer in Scotland was a subsidiary of a firm in the south of England. Where the bulk of R & D was performed. Nevertheless, the evidence from Table 5 shows that differences in industrial structure do not explain the whole story. It is difficult to believe that industrial structure changed as radically as these figures imply over such a short period. Even if, however, a backward industrial structure were the main problem, the treatment given to the role of science in Scottish economic development is scarcely adequate bearing in mind the ramifications of the subject and later developments in knowledge of the R & D process. Put another way, the fact that industrial scientific commitment depends upon industrial structure does not excuse us from investigating fully the reasons why industrial structure has taken this

[23] _Ibid._, appendix 3.

form and, more importantly, whether there is anything unique about science-based industry which would tend to reinforce this situation.

To some extent the Toothill Report examined the former as we have seen, pinpointing the major problem as being an under-representation in the fast-growing sectors of national industrial production. It also recognised that many of these sectors are 'science-based'; that is, they are relatively closely involved, directly or indirectly, with advances in the natural sciences and/or applied sciences. What it did not do was to develop a fundamental rationale and articulation of the nature of the interaction between the 'science system' and the 'manufacturing system', specifically on a regional basis, which would help to clarify Scotland's technological backwardness, its historical causes and its continuous persistence. This is curious since the Report seemed to be aware of the general problem. Thus it recognised the importance of "maintaining contact with scientific and research centres... where the product involves advanced technology"; it recognised the importance of the 'communications' factor where "industries (are) not tied to particular locations for other reasons"; it was aware of the external economies involved in having a number of "component and specialist subcontractors for engineering and many other industries" close at hand; it was aware of the technological importance of the government market especially from the point of view of development contracts. Finally it made certain specific recommendations which might bring Scottish industry more into contact with the science system. These were:

a) Improved communications between North and South - specifically better air communications.

b) Greater participation on the part of Scottish industry in the funding of government R & D contracts.

c) The possible siting of future government R & D establishments in Scotland.

d) Improvements in sources of credit and finance for R & D.

Nevertheless it is difficult to avoid the conclusion that these recommendations were made on a rather 'ad hoc' basis, without any fundamental analysis of the complex relationships that exist between scientific advance and industrial development. Thus the Report recommended that no special advantages should be given to Scottish firms regarding manufacturing contracts, although we have seen in Chapter III - see also Chapter VI - that for the firm there are marked technological advantages involved in selling technologically-intensive products, and since the government is an important buyer of such products it would seem that discrimination in favour of Scottish industry could have been an important and effective means of raising the level of Scottish technology. In any case, since commercial considerations are the most important for any firm,[24] there would seem to be little point in a firm taking on complex R & D contract work if, at the end of the day it were still to be at a disadvantage in selling the products stemming from this new technology; as, of course, it would be if close user/supplier relationships were necessary at the production stage.

Nor was any analysis made of the various forms in which new technology

[24]Leaving aside pure 'R and D firms', which in Scotland are an exception.

reaches the firm. Thus quite apart from ordinary personal communications there are a variety of information services, links with related companies, secondments, privately contracted R & D contracts and so on. An important and related gap here was the lack of any consideration of the scientific infrastructure as a whole. Thus although government research establishments are under-represented in Scotland it is important to recognise that there are other institutional sources of technology such as universities, technical colleges, research associations and other specialised non-profit institutions which might have been at least potential alternative sources. Finally little was said about the dynamics of the process; to what extent, for example, would new companies be spun-off from local research bodies, to which particular industries would these firms be related, to what extent would a lack of further institutions with certain specific sets of expertise, prevent the establishment of a scientific/industrial complex of the necessary critical size with respect to one industry or a number of industries, and so on.

I do not wish to be too critical of the Toothill Report since clearly it was considering the whole range of Scottish developmental problems and could not at that time have justifiably put a lot of effort into a detailed examination of the, admittedly very complex, interrelations between science and industry and its implications for development. Nevertheless the fact that so much emphasis was placed upon industrial structure as the fundamental key to the problem, and the explicit recognition of scientific and technological factors as being inherently bound up with modern industrial developments might together have warranted a closer look at this whole area.

5. <u>The Enquiry Framework</u>

It has been the intention of this thesis to go some way towards filling this gap both theoretically and empirically. That is to examine the extent to which there are certain factors peculiar to science-based industry which act so as to reinforce traditionally recognised pressures causing industry to concentrate its activities in specific localities. In Chapter III I argued that not only is there evidence to show that scientific activities and science-based industrial activities do concentrate themselves in this fashion, but also there is good reason to expect that this will normally be the case in the absence of specific countervailing government pressures. In this chapter I have discussed the case of Scotland as being an example of a region which is, relatively speaking, technologically backward, which displays the normal symptoms of structural underdevelopment - net emigration, high unemployment, backward industrial structure, etc. - and for which there is a certain amount of evidence to suggest that industrial R & D performance is inadequate and not entirely explicable by a deficient industrial structure. There may be many reasons for this. Thus one suggestion is that typically firms are smaller in Scotland than in England and since it is well known that small firms spend proportionately less on R & D than medium-sized firms it follows that there will be less Scottish R & D effort. But this explanation merely leads on to the question 'why should Scottish firms be typically small?"

One explanation might be that within each industrial sector the firms that appreciate the importance of innovation and technological change are typically the smaller firm started off by new (and younger) entrepreneurs, and not the older well established firm. The Toothill Report certainly hinted that this reason should not be ignored. A second possible explanation for the poor Scottish R & D performance might be that within the considered industrial sectors there is a tendency for Scottish firms to concentrate on the less technologically intensive areas of production or, alternatively, that Scottish firms tend to be at the tail-end of the technological spectrum. Finally, it may well be the case that many Scottish firms are subsidiaries of English or overseas-based companies which tend to concentrate most of their R & D activities elsewhere. Such firms may be purely sales outlets or manufacturing concerns (e.g. S.G.S. Fairchild at Falkirk or Pye at Airdrie) producing and selling equipment developed south of the border or overseas.

In addition, there is evidence to suggest that Scotland is under-represented in terms of certain important types of public and semi-public research institutions, many of which are concentrated in the south-east of England and in the Midlands. Thus in Chapter III we have seen that although Scotland has about 15% of all research stations, 87½% are stations whose activities are not directly relevant to the new 'science-based' industries which Scotland might hope to foster.

The question is then - are these two sets of factors (imbalance of industrial structure on the one hand and under-representation in terms of a viable technological under-pinning on the other) interrelated? If so, does this feature have any implications for future regional development in Scotland? We have seen that the scientific infra-structure acts as a source of many different types of technical expertise.

Moreover, it is also the possessor of various types of specialised research facilities and personnel which no one firm, unless it were very large, could afford by itself; clearly there will be advantages in physical proximity to such facilities. The scientific infrastructure acts as an important market for technologically-intensive products and as a source of development contract funds. Again we have seen that there are important advantages from close physical proximity between buyer and seller with respect to the manufacture of sophisticated products. Finally we have seen that scientific activity tends to cluster and that scientific/industrial complexes have an internal dynamic of their own; the larger is the complex of science-based firms and scientific laboratories the greater will be the number of firms wishing to set up activities in that region. From the point of view of regional development, therefore, the ease with which new science-based industries can be set up will be an inverse function of the size of the relevant scientific infrastructure and of the number of science-based firms already in existence. This has two important implications:

a) To the extent that science-based industries are the fast-growing sectors in an economy, future prospects for faster economic growth in any region will be poorer the smaller is the size of the scientific infrastructure relative to other regions.
b) Firms already in this region will be at a competitive disadvantage through unequal access to appropriate technologies and consequently will find it more difficult to expand output in industries where technological advance is rapid.

Thus it is reasonable to suppose that the concentration of outside research bodies in the south-east of England may well have a strong centrifugal effect on research-orientated firms and it is possible that sheer physical distance of industry in, say, Scotland from such centres of research will have a profoundly inhibiting effect upon the prospects of:

a) growth of firms already extant in Scotland,

b) attracting new technologically-based activities into Scotland.

Clearly in the absence of countervailing pressures overall economic growth in Scotland will suffer. This analysis suggests the following basic hypothesis: <u>that geographical distance from research institutions significantly inhibits the ease with which private industry may maintain contacts with these institutions and that this will be reflected in the extent of contact actually made</u>. In the event of this hypothesis being supported by the evidence, a subsidiary hypothesis emerges: <u>that this situation has a significantly deleterious impact upon the effective research capacity of science-based industry in Scotland and consequently upon the rate of growth of such industry</u>. Clearly if the first is rejected very little can be said about the second.

Concentrating upon this feature of the problem I decided to examine the electronics industry as being a typical example of a new, science-based industry which has tended to concentrate its activities in the south of England. On the surface it would be expected that this particular industry is less likely to experience the same pressures traditionally recognised as being responsible for industrial location. Thus it is not dependent upon geographically localised sources of supply; it is labour-intensive with low initial capital requirements and would naturally, it is supposed, site itself in areas where labour is plentiful; it would not even be considered particularly market orientated since, most of its products are easily transportable. The fact that it has nevertheless concentrated itself in the same area as many important centres of scientific and technological excellence may not be purely coincidental and it was felt that an examination of the relationships existing between a sample of firms and the scientific infrastructure would be revealing.

The enquiry has centred around the nature and extent of technological contact between a sample of electronics firms and 'outside research bodies'. The latter include mainly the various government research establishments, the industrial grant-aided research associations and universities and technical colleges. In addition the use made of outside library and information services was investigated. Finally, for reasons outlined in Chapter V the enquiry was left sufficiently open-ended so as to comprehend any further sources of technical expertise which the firms felt to be important to their activities. The questions to be investigated may be categorised into two general areas:

1) <u>Type and extent of contact</u>

a) With what particular bodies and types of bodies are contacts maintained?

b) What forms do these contacts take?

c) How widespread are these contacts? Are there certain bodies or types of bodies which are particularly important in this context?

d) Finally, outside the original framework of the study, are there other sources of technical expertise, which to some extent act as alternatives to the research bodies considered in the survey?

2) Regional differences

The sample was split into two sub-samples taken from different geographical regions, viz. central Scotland and the south-east of England. These sub-samples were chosen so as to be as similar as possible with respect to type of activity, size and relatedness to overseas companies. Thus matched it was felt that any differences in type and extent of contact between outside research bodies and the respective sub-samples chosen would be highlighted net of extraneous factors. In particular an attempt was made to obtain answers to the following questions:

a) Are there any significant differences between the sub-samples with respect to questions a) to d) in category 1).

b) Is there any evidence to support the corollary hypothesis that firms will tend to have their most important contacts with outside research bodies sited in their own particular geographical area? i.e. Is there any evidence of 'localisation'?

c) Do Scottish firms experience any particular disadvantages arising from geographical distance from the main outside research bodies relevant to their activities?

A detailed account of the methodology adopted, the choice of the sample, the limitations of the data and the problems encountered in the research is presented in Chapter V.

CHAPTER V

METHODOLOGY

In this chapter details are presented of the experimental technique adopted. Specifically it is split into three parts; firstly an overview of the research strategy, secondly a discussion of the mixed case-study/questionnaire approach, and finally a discussion of sampling procedures.

1. The General Strategy

Essentially the study was conducted in three phases; viz the initial evolution of the questionnaire and a preliminary pilot survey, the Scottish survey, and finally the English survey. The questionnaire was originally drawn up on the basis of a general appreciation of the literature and an *a priori* assessment of the important variables. After a certain amount of discussion with my supervisors a revised draft questionnaire was evolved which was then used in discussion with four pilot firms. A certain amount of further revision was made over the course of the pilot survey. At this stage an approach was made to the Edinburgh office of the Ministry of Technology who agreed to help in a number of ways. Specifically they agreed to send out a circular letter to the original Scottish sample explaining the nature of the enquiry, stressing its importance from the point of view of Scottish industrial development and urging that full co-operation be given. They also provided considerable help in choosing the sample since they had at their disposal details of firms which carried out appropriate research and development. Finally they were able to assist generally by virtue of their specialised insights into the current industrial situation in Scotland and with respect to the types of questions contained in the questionnaire.

Having agreed on a final questionnaire format, the questionnaires were sent to the Scottish sample (after the Ministry of Technology circular) along with a covering letter which reiterated the aims of the enquiry and explained that I personally would be contacting the firm by telephone to arrange interview dates. Special emphasis was placed upon the confidential nature of the research and an assurance was given to the firms that every effort would be made to ensure the secrecy of individual returns. Finally contact was made with each firm by telephone. This stage was facilitated by the fact that the Eurdec Guide gave names of specific employees (with their positions) and also since in a number of cases the Ministry of Technology had knowledge of appropriate personnel. Nevertheless, it frequently took two or three telephone calls before a viable contact was established. An effort was made to establish contact initially with managing directors and, failing that, with research directors or chief engineers. Very often interviews were conducted with several members of a firm's staff and occasionally several separate interviews were held. Both the length of the interview and the number of interviews held depended fundamentally upon the interest and enthusiasm shown by the firm.

The same general procedure was followed on the English survey. The Edinburgh office of the Ministry of Technology requested the London office to send out a circular letter. This was followed by the questionnaire plus covering letter from myself which was followed in turn by the telephone contact to arrange interviews. As in the Scottish survey interview times varied between under an hour and several hours depending upon the respective attitudes of the firms.

2. <u>The Questionnaire/Interview Approach</u>

The technique of research adopted was essentially that of a series of case-studies of a number of firms, although each firm was also asked to complete a fairly detailed questionnaire which, as may be seen in Appendix I, splits logically into four parts. Part I was concerned with a number of general indicators of the relationship, if any, between the firm and other private manufacturing establishments. Part II consists of a series of questions designed to obtain a structured pattern for the nature and extent of the relationships existing between the firm and outside research bodies. Part III consists of a series of statistical questions relating to the firm's research and development activities while the questions in Part IV deal with general economic indicators of the firm's activities.

Although it was always intended to conduct the survey on a personal interview basis, it was hoped originally that the questionnaires would provide most of the substantive data. However, it became clear as the survey progressed (a) that the questions in Section II of the questionnaire elicited responses which <u>by themselves</u> were inadequate and (b) that the questionnaire itself was too long and involved.

The detailed statistical questions were included in order to evaluate firms' contacts in the light of the level and structure of their R & D expenditures and how these had varied over recent years. It would have been interesting to ascertain, for example, whether firms with a high and growing internal R & D effort (measured, say, by R & D/sales) had different contact experiences from those whose spending upon R & D was small. In fact, however, the likely response of firms to these questions was overestimated. Apart from the natural reluctance of manufacturing industry to divulge data of this type (especially sales and profit data), the firms were already heavily involved both with the interviews and with Sections I and II of the questionnaire. In addition much of the relevant statistical material was not readily available and its assimilation clearly would have involved a lot of work. Since it was of primary importance to have Sections I and II completed, firms were eventually requested to be sure to complete these and to complete the remainder only if they could spare the time and effort. In the event response to Sections III and IV was very poor indeed and these sections were disregarded for the final analysis.

As far as Section II is concerned it became clear that while much of the data gathered was both relevant and useful, it only gave a limited appreciation of the true nature of the relationship and did not lend itself easily to expression in 'objective terms'. There is, for example, no statistical proxy for 'extent of contact' for the very good reason that such a concept comprehends a wide variety of forms, the acquisition of data for which was found to be a well-nigh impossible task. Contact may take the form of telephone calls, letters, visits, personal acquaintances, use of a variety of facilities, secondment and so on - the list is endless. The difficulties are two-fold. Firstly, how to go about the collection of accurate data on each of the different forms of contact and secondly, how to apply 'weights' to each measured form of contact in order to arrive at a valid overall contact measure for the firm.

With regard to the first difficulty it very quickly became apparent that to obtain data on any one form of contact, say telephone calls, over a period of time would be an arduous task involving various of the firm's personnel in a considerable amount of paper work. Thus very often no written records had been kept, personnel had left the firm, etc., and even where data existed the collection and assimilation of it would have involved a great deal of effort. Moreover, leaving aside its meaningfulness, there was no guarantee of accuracy since much would depend upon personal memory. The second difficulty relates to the question - what meaning can be attached to the data? Even if, for example, it were possible to document accurately the number of visits (and their durations) made between firm X and the University of Y what insight would this give as to the technological and/or financial value of these visits to the firm in question? Again, on what basis would it be possible to attach 'weights' or 'values' to each individual visit, to carry out a parallel exercise as between the various forms of contact <u>and</u>, similarly, as between the various types of outside research body?

Quite clearly there are prodigious methodological problems involved and it became quite evident that any attempt to solve these questions with any degree of rigour would have involved concentrating upon depth studies of a handful of firms - very probably just one. While such an exercise may have contributed substantially to the theory of sociometric analysis it would have taken the research far away from the original objective of this thesis, which was to examine the nature and extent of contact between a significant number of firms and outside research bodies, and to examine the regional impact of this contact. For these purposes it was not vitally necessary to have rigorous absolute measures of external technological inputs. What <u>was</u> necessary was that the analysis should be so framed that, apart from describing and exemplifying the nature of the technological relationships, it should go some way towards isolating the regional impacts. To this end the analysis should consist of a comparison between two geographically discrete samples constrained to be as similar as possible to each other. The evolution of these samples is described below.

However, this discussion is not to say that no attempt was made to quantify. On the contrary quantitative measures were sought wherever possible. Rather it is intended to emphasise the following points:

(i) Whilst at the beginning of the survey the intention had been to rely on the questionnaire returns as the major data source and to use the interviews to provide the background material, very quickly the process was reversed. The questionnaire returns provided the 'bones' but the 'flesh' came from the interview transcripts. This process took place mainly as a result of the experience gained during the pilot survey.

(ii) In the results presented in Chapter VII great care should be taken in interpreting the quantitative data presented. More specifically they should be read in the context of the qualitative analysis.

(iii) Of necessity a certain amount of subjective assessment has been involved. It is made clear in the text where these assessments have been made.

The interviews were conducted along the following lines. Firstly the firm was asked to give a description of its product lines and its recent history. Then questions were asked about the firm's contacts with each category of outside research body and the importance of these contacts to its activities. Finally questions were asked in connection with use of library and information services, and any other outside sources of technology which the firm made use of. This was the rough structure of each interview. However, I did not feel constrained by this structure and often probed deeply into a particular contact which seemed important to the firm concerned or which seemed to reveal an important facet of the relationships. In this sense the methodology approached that of a series of case studies. The notes from each interview were written up into a series of transcripts which were subsequently used as a data source for analysis.

3. The Sample

Altogether 52 firms (25 Scottish, 27 English) were approached of which 34 agreed to co-operate. Of these two were used purely for the pilot survey, two were found subsequently to be unsuitable - both English firms - and one Scottish firm gave only limited co-operation. Including the latter gave a sample of 30 firms (14 Scottish, 16 English). The Scottish sample was chosen from the 'Interlab Index' compiled by the Scottish office of the Ministry of Technology. This list gives details of Scottish firms which have R & D facilities and are engaged in manufacturing. Considerable help was also given at this stage by officers of the Ministry of Technology who were acquainted with the operations of many of the local firms in the electronics industry and could, in some cases, recommend appropriate personnel to contact. As mentioned above[1] they also sent out an initial circular letter preparatory to my initial telephone contact.

The chief difficulty at this stage was the small size of the electronics industry in Scotland.[2] The Eurolec Guide[3] gave details of around 50 electronics establishments then operating in Scotland but a number of these were purely sales offices for firms manufacturing elsewhere. In addition a number of firms were solely manufacturing affiliates of organisations whose R & D was conducted elsewhere. Eventually 23 firms were identified which were known to carry on development activities.

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[1] See Section 1.
[2] See Chapter V.
[3] "Eurolec G.B. Pocket Guide: a Source of Basic Information on Companies Active in the Electronics and Instruments Industry in Great Britain", 1967 and 1968 editions, David Rayner Associates.

Of these eight refused to co-operate and one other agreed to assist but, unfortunately, was burnt down before the interview date. This gave a Scottish sample of 14 firms, two of which were asked to co-operate both in the pilot and in the main survey. In addition one firm in the chemicals industry and one firm in the electrical engineering industry provided valuable assistance at the pilot stage.

In choosing the English sample the procedure was as follows: Initially a gross sample of 300 firms were chosen from seven counties in the south-east of England on the basis of whether an estimate was given of number of employees. From this gross sample three counties were chosen spanning a belt of country 30-70 miles from the centre of London (viz. Berkshire, Hampshire, Sussex). This left a sample of 70 firms from which a final sample of 27 was chosen on the basis of the following factors:

(1) Size of establishment (as measured by number of employees).

(2) Affiliations to overseas companies.

(3) Type of activity.

The design of the experiment was regarded as being important since establishing differences in contact due to geographical factors pre-supposes other influences being held equal. It may be, for example, that the larger a firm the more is it likely to be able to spare members of staff for establishing and maintaining contact, and the larger the interests and spread of outside research bodies likely to be associated.[4] In addition the wider the interests of the firm and the larger the technical staff the more likely it may be that personal

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[4] Although as pointed out in Chapter 3 and below it may be that the larger firms will require <u>less</u> outside research contact because of greater self-sufficiency.

contact will be built up with these bodies.

It does not follow, of course, that a firm with wide interests is a large firm or (more realistically) vice-versa. Consequently an attempt was made to match both sub-samples by type of activity. Further it was reasoned that firms manufacturing standard product types for which the technology is well known and widely diffused would be less likely to require outside technical contact than firms operating at the frontiers of knowledge. Subsequently this was found to be not necessarily the case. Where a firm is operating with a very advanced technology it may be, so to speak, out on its own. For example, one division of a large Scottish firm had very little contact with outside research bodies despite its advanced technological character. It maintained that its technology was either self-generating or stemmed from a related overseas company and insisted that this was entirely adequate for its needs.

Nevertheless it was felt that an attempt should be made to match firms by type of activity. In fact this proved to be a very difficult exercise mainly due to a lack of a priori information. The Eurolec Guide Book provides a list of products for each firm but it was impossible to assess either the relative importance of products to each firm's activities or the degree of technical sophistication of products. The mechanism of sampling consisted in endeavouring to match up each Scottish firm with two corresponding English firms for which relative size correspondence had already been attained. The criterion used was that firms should mention similar products in their respective lists. It was, however, not really possible even to go this far since there remained a few Scottish firms which had no direct equivalent by type of activity.

The sample was further stratified with respect to number of firms who were subsidiaries of overseas companies. Four out of the fourteen Scottish firms and six of the sixteen English firms (which responded favourably) fell into this category. All of these were related to U.S.-based companies. It was felt that these firms would be in a rather different position from indigenous firms both with respect to flow of information and to type of development carried on. It was found, for example, in the case of one such firm in Scotland that a significant part of its R & D effort was concerned with altering existing products to suit conditions appertaining to British markets and in the case of two other firms heavy use was made of information provided by their respective parents. Such access to research results, it was felt, would make it less likely that this type of firm would require close contact with outside research bodies. Subsequently, however, this was found to be not necessarily so. The subsidiary firms were all medium-sized firms but as far as they were concerned there was no direct correspondence by type of activity between the Scottish and English sub-samples. While, therefore, there was no overall one-to-one correspondence between the sub-samples in terms of <u>all</u> the selection criteria mentioned above, it was felt that in the final analysis the two sets of sub-samples were fairly well matched in terms of product type, size, range of technical sophistication and relatedness to overseas companies. Initially two English firms were contacted for every Scottish firm both in order to allow for non-response and also in case there should happen to arise an obvious mis-match. In point of fact two English firms were rejected on these grounds. Out of the remaining 25 firms, nine refused to co-operate for one reason or another which left a final sample of 16 English firms.

Finally mention should be made of the decision to concentrate the effort on small and medium-sized firms (i.e. firms in general of less than 500 employees). In a sense I had little choice in the matter. Having taken the decision to examine the electronics industry, I was immediately constrained by the fact that many firms in this industry are small. Moreover, this is especially true with respect to the Scottish sector which was in any case rather small in itself. Nevertheless, the decision does lend itself to rationalisation in the following ways. To the extent that smaller firms have fewer resources to commit to the R & D effort it was reasonable to suppose that they might tend to rely rather more upon outside sources of technology;[5] in this sense an examination was being made of an extreme case in which, if any difference existed, it was liable to be picked up more easily. Furthermore it was felt that concentration upon a fairly cohesive sample of this type would provide some important insights into one aspect of regional development policy; viz. the possibilities of attracting small-size, science-based firms into an underdeveloped region. Finally there are, of course, distinct methodological advantages in narrowing the bounds of a study of this type. It follows, however, that it is less easy to generalise the results, although it is hoped that whatever insights, either methodological or substantive, are generated from this piece of work may be of use in similar studies.

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[5] This may be so, for example, because of the necessity of having a certain minimum R & D 'threshold' effort. See Freeman, op.cit., Chapter II, note 58.

CHAPTER VI

THE EMPIRICAL EVIDENCE

This chapter has been divided into four sections. Section 1 deals with contacts with research associations. Section 2 deals with contacts with academic bodies while Section 3 examines the relationships found with government research establishments. In each of these I have examined the nature of contact, the important bodies in each case and regional differences. In Section 3 particular attention is paid to development contract work.

Section 4 deals with use made of library and information services, other contacts not included in the foregoing chapters but included in the questionnaires, and finally contacts of a technical nature with private industry, particularly with related companies. At the end of each section there are summaries of the main inferences to be drawn. In the following chapter I draw the various conclusions together in the context of the original enquiry framework.

1. Research Associations

The industrial grant-aided research associations as a whole offer a wide range of services to members as well as a limited range to non-members. The extent of these varies from association to association and it is possible in some cases to take advantage of a particular service even if a firm considers it not worth while to join. For example, the Scientific Instruments Research Association (S.I.R.A.) offers an abstracting service on payment of a specific fee to non-members. In the sample an attempt is made to assess the amount of use made of these bodies, the type of use made and whether or not there was any significant difference with respect to the Scottish and English samples.

Types of Service[1]

The various services offered may be categorised under the following headings:

(i) Information Services

All research associations offer library and information services and in many cases non-members may borrow or have sent for a fee, books, abstracts, reports, etc. on the industry, its technology, management, related sciences and very often relevant patent and legal material.

(ii) Technical Enquiry, Testing and Consultative Services

Advice on a wide range of facets of the relevant technology is usually given by information staff. Very often these enquiries relate to a particular area of technology being investigated by the association where the firm has a particular idea with regard to product or process improvement. Such enquiries are open-ended and relate specifically to what is generally understood as diffusion of techniques. However, the majority of technical enquiries relate to specific products, their evaluation, design, faults, etc. In addition, many research associations are willing to lend test equipment to members. Consultative services - charged to members at full economic cost - tend to lie in the sphere of operations research, e.g. factory layout, stock control, cost analysis, etc.

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[1] For more complete detail on these see "Technical Services for Industry", (London, Ministry of Technology, 1967), pp.35-109, and "Industrial Research Associations in the U.K.", (Paris, O.E.C.D., 1965).

(iii) Liaison and Public Relations

This involves visits to members to give on-the-spot advice on particular problems. There is also, of course, a definite effort to recruit new members since the size of the government grant to the association (and hence the total budget) is directly related to level of industrial incomes. Several of the firms in this present study mentioned the assiduous efforts of research associations to persuade firms to join.

(iv) Training Courses

Very often these are held in collaboration with technical colleges.

(v) Repayment Work

This consists of research projects sponsored by firms and may be split into two categories:

(a) As a member service which is available to members on demand but unless there is a feedback to the co-operative programme or unless other members can benefit, the service is charged for.

(b) Confidential sponsored research in which the member is charged full economic cost in return for exclusive ownership of results and patent rights.

Not all associations are willing to do repayment work and in the case of confidential work only two - viz. the Production Engineering Research Association (P.E.R.A.) and S.I.R.A. - actively seek it. In fact, of the total volume of confidential sponsored research performed in the U.K. research associations, P.E.R.A. does well over half and S.I.R.A. does more than half of the remainder.

TABLE 1

SPECIFIC MEMBERSHIP CONTACTS[2]

	Total	Scotland	England
B.W.R.A.	2	1	1
E.R.A.	2	1	1
S.I.R.A.	3	1	2
P.E.R.A.	2	2	0
M.T.R.A.	2	1	1
Total	11	6	5

TABLE 2

NUMBER OF FIRMS WITH R.A. CONTACTS

	Total	Scotland	England
No. of member firms	8	4	4
Intending to join	4	1	3
Foregone membership	7	4	3
Non-member use	4	2	2
Total firms	30	14	16

[2] B.W.R.A. = British Welding Research Association. M.T.R.A. = Machine Tool Research Association. Three firms were members of more than one R.A. None were members of more than two.

Use Made: The Sample

The electronics industry does not have any particular research association uniquely relevant to its activities and there has in the past been a certain amount of criticism of this state of affairs. However, cursory examination of the existing associations makes it clear that such bodies are either concerned with specific products or with precisely defined technologies, e.g. British Welding Research Association, British Jute Research Association, British Machine Tools Research Association, whereas the electronics sector comprises a wide spectrum of technologies from radio manufacture to computers. Moreover the rate of innovation in much of electronics is such that any one research association would be hard put to maintain an adequate familiarity with the many relevant disciplines. It should also be pointed out that certain existing research associations would appear to be capable of serving the interests of electronics firms - most notably P.E.R.A., S.I.R.A. and E.R.A. - and that certain research establishments and universities, operating as they do on the frontiers of knowledge and with no particular responsibility to any industrial sector, may be far better endowed to fulfil the role for an advanced industry like electronics that for more basic and unified industries is fulfilled by the various research associations.

Certainly this would explain the picture that emerged from this particular enquiry. Out of a total of 30 firms only 8 were members of a research association, and of these only three considered that membership was anything more than minor significance to their activities.

In each of these physical distance did not seem to prove a handicap. All three firms were members through their parent companies and in the case of one, a member of P.E.R.A., the membership had arisen by virtue of the fact that its parent company's headquarters were located in the same areas as those of P.E.R.A. The English firm, a member of S.I.R.A. was also located close to S.I.R.A. headquarters. Four others made sporadic non-member use of particular associations, seven firms had foregone membership for various reasons (see below), while four others were considering joining. Comparing the Scottish and English samples showed a parallel experience. Certainly there was no evidence that extent of contact was smaller in the case of the Scottish sample. 25% (29% Scotland) of the English firms were members of research associations, 21% (9% Scotland) were intending to join, 19% (29% Scotland) had recently foregone membership, while 12.5% (14% Scotland) made non-member use on occasions.

All four Scottish firms maintained that their main use was that of technical reports and library facilities, in two cases relating to particular techniques in which the research association was known to have expertise. Thus one firm manufacturing micro-components is a member of the Welding Research Association (B.W.R.A.) and finds it worthwhile to keep abreast (through technical reports) of latest developments in precision welding, a necessary input in their manufacturing process. Such contact need entail no physical contact (although in fact one visit is made per year) and is a good example of a mutually beneficial linkage in which geographical factors are of minor importance. It is significant that the same firm forewent membership of another research association not only on technical grounds but also because ensuring that their membership was worthwhile entailed frequent visits to London. In this case an alternative source of expertise (a local university) was available.

The experience of the English members is much the same. All four received regular reports on particular areas of technology in which the various R.A.'s had expertise. Thus one firm manufacturing 'intrinsic safety equipment' received regular reports from the E.R.A. which had done specialised work in this area. Two firms used the instrument evaluation and testing facilities offered by S.I.R.A. In no case was any use at all made of training facilities but there were nine examples of research problems referred to research associations in 1967 (see Section 4). The same picture emerged in the case of firms making non-member use of research associations; viz. approaches made in respect of particular technologies and usually on a once-and-for-all basis.

The rationale given by firms who made no use of research association facilities was generally technical. Most of them seemed to be aware of the main types of services and had considered the possibility of joining. One firm had even gone so far as to give P.E.R.A. a 'test exercise' in the research sense before finally telling the association that it could see no benefit in joining. Both Scottish and English firms maintained that there was little advantage in joining having in mind the cost - often relatively large for the smaller firm - and the fact that there were often alternative sources of knowledge available. Only two firms mentioned geographical distance but both maintained that technical considerations were more important. The same reasons held for firms who had foregone membership, viz. the amount of assistance received from associations was far smaller than the resources committed in terms of annual subscription.

Summary

In the sample the main examples of 'useful contact' occurred in situations where a specific area of research association knowledge happened to coincide with the interests of the firm. In general, however, contact with research associations is not strong (see Tables 1 and 2). 60% of firms had no contact of any kind with research associations and in fact only around 10% of the research associations in the U.K. were mentioned at all. Of these (five) only one was mentioned by more than two firms - viz. S.I.R.A. The main use made seems to have been that of library and information services. When comparing the Scottish and English samples I did not find any significant differences either in degree or type of contact. Certainly extent of contact was no smaller in the Scottish case. Neither was there any strong evidence of localisation of contact.

2. Academic Bodies

It is widely acknowledged that nowadays, more so than ever before, there is the possibility of a wide and mutually beneficial interchange between universities and technical colleges on the one hand and industry on the other. This is especially the case with science-based industry and the natural science and engineering departments of academic bodies. In this regard academic bodies[3] are in a rather different position from the research associations discussed in Section 1, since the latter are constrained by virtue of their commercial viability and hence their inevitable concentration on work of an essentially practical and limited nature of immediate relevance to the majority of firms in a particular industry. However, most postgraduate and research sections of university departments are operating on 'the frontiers of knowledge' and although they do not offer[4] the same range of services as research associations, are extremely valuable sources of high-level expertise.

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3. 'Academic bodies' should be taken to include universities and technical colleges of all types.

4. Strictly speaking, of course, academic bodies do not 'offer' any services since this is not one of their functions.

The capabilities offered by academic bodies may be categorised as follows:

(i) Facilities for research projects. Such projects would not generally be undertaken by firms themselves either because of lack of staff and other facilities or because the firm themselves felt that the disinterested character of basic research in the commercial sense rendered it an unsuitable activity for R & D departments primarily concerned with problem solving of a more immediate nature.[5] On the other hand firms may be willing to subsidize - or even completely fund- research projects at academic bodies. Although the firm will not in general be allowed exclusive rights of results of such research it will usually be aware of them well in advance of competitors since during the period in which research is being conducted there will be informal contact between firm and academic body. There are also possible advantages for the firm with respect to possible future recruitment of scientists and engineers.

(ii) Consultancies. It is well known that many members of university staffs act as consultants to industry. This may be on a formal or informal basis and in the latter case is often the result of personal friendship. The benefits here are too obvious to be stated, but it

[5]It is interesting to note here that in the large majority of firms here practically no 'basic research' is carried out. R & D staff are mainly concerned with circuit design, routine equipment testing etc. which should more properly be regarded as necessary inputs in the productive process rather than activities designed to expand production possibility curves. An interesting and illustrative example of this important distinction was given to me by one chief engineer in connection with electro-chemical machining of hard metals - it is well known that a nitrate electrolyte gives a far smoother machined surface than a chloride solution although why this is so no one knows. It is sufficient therefore for the firm to use the former. This, however, is the type of problem they would 'farm out' to a university laboratory in the hope of a radical advance in machining technology.

should be noted that these contacts are often of considerable benefit to the consultant who is made aware of the type of work being done in industry and consequently of the areas of technology most susceptible to commercially productive research. From the interviews it was found that a number of academic staff are cognisant of the need for closer co-operation between industry and university and are taking steps to remedy the situation.

(iii) Testing facilities.

(iv) Library facilities.

Results of the Survey

In the survey an attempt was made to assess the degree of contact with universities and technical colleges, its type, extent and how important it was regarded by the firms interviewed. I also attempted to find out about the extent of 'localisation'[6] of contact and in addition I considered the different experiences of the Scottish and English sub-samples.

Type and Extent of Contact

Academic contacts tended to fall into the first three category types mentioned above. Occasional use is made of library facilities but this is sporadic and where a firm does use outside library sources these tend to be either those of professional institutes or national organisations such as N.L.L.[7] (see Section 4). This may arise, of course, because of restrictions on borrowing books from university departmental libraries. Put another way, unless there are further

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[6] i.e. to what extent there is any distinct tendency for firms in a particular geographical area to make and maintain contact with academic bodies in that area.

[7] National Lending Library for Science and Technology.

__Addendum:__ In assessing differences between the Scottish and English sub-samples revealed by this research it is possible in some cases to use a χ^2 test for goodness of fit. In each of these cases (Tables 3, 8, 10, 12, 14 and 17) this has been done by taking the English sub-sample as the standard and "normalising" the appropriate frequencies to take into account differences in numbers of firms; by then treating the Scottish sub-sample as the "observed" sample; and finally by testing the null hypothesis that there is no significant difference between the sub-samples with respect to the particular characteristic in question. Caution, however, is advised in the interpretation of these tests for the following reasons:

(a) The χ^2 statistic is only an approximation to the true distribution it is supposed to measure. More specifically, when the "observed" and "expected" frequencies are < 5 inaccuracies creep in. (See, for example, P.G. Hoel: "Introduction To Mathematical Statistics", John Wiley & Sons Inc. N.Y. 1962, page 247). This has meant that it has not been possible to perform a χ^2 test where this would have been appropriate (e.g. contact with research associations). In other cases (Tables 3, 8 and 10) I have included a frequency of < 5 in the calculation, because of the small number of observations available.

(b) More importantly perhaps, as described at length in Chapter V (see section 2) the quality of the data is not such that definitive conclusions can be drawn.

links with a particular department it may not be possible in general for a firm to use the department's library facilities since these are intended purely for the use of students and staff. In addition there did occur examples where a particular consultant suggested a source of literature and it is uncertain to what extent there is <u>indirect</u> library usage of this type. As will be seen later, however, more often than not alternative sources of literature are available.

TABLE 3

FIRMS WITH ACADEMIC CONTACTS

Number of Firms	Total	Scotland	England
At least one contact	24	11	13
More than one contact	16	8	8
No contact	6	3	3
Strong contact	10	6	4
Total firms	30	14	16

$\chi^2 = 2.35$ with 3 degrees of freedom. This is not significant at the 5% level (see enclosed addendum).

Sixteen of the 24 firms had contact with more than one university, (8 Scotland, 8 England). It is difficult to categorize precisely the form these contacts took since very often particular examples shade into one another. For example, in a number of cases firms are in the habit of suggesting areas of research for postgraduates in a particular department, but at the same time have an informal consultancy arrangement with the students' supervisor. Again the use of specialised test facilities often involves a certain amount of consultation since the appropriate member of staff will have specialised knowledge on the ramifications of the tests being carried out. A rough count gives eleven examples of test facilities being used. These usually related either to specialised equipment which was not worth the while of the firm to install for itself (e.g. wind tunnel facilities at Southampton) or else to the type of work often done at universities for teaching purposes, e.g. determining characteristics of materials under specified conditions of temperature, pressure, etc.

There were sixteen examples of formal and informal consultancy arrangements, generally in cases where a particular university department had specialised knowledge in a field. Thus the Department of Geology at Edinburgh University is currently investigating problems of X-ray fluorescence analysis and an Edinburgh based firm which manufactures medical equipment takes an active interest in developments there.

There were eight examples (2 England, 6 Scotland) of firms giving[8] research projects to university departments and experience here varies quite a lot. On the one hand there is a strong predisposition to regard universities as sources of long-term basic research rather than as centres where immediate development problems may be solved, while on the other hand I came across examples where short-term work was done. Admittedly this type of work could almost be described as 'testing' since it usually boiled down to examining the reliability of components and instruments in various sorts of environment. Nevertheless these were given to the university departments as 'research projects' typically for final year undergraduates who are required to complete a short dissertation for their first degree. Thus an

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[8] i.e. in the 'habit' of giving. Some of these firms did not have a project on hand at the time of the interview.

employee of one firm was also a part-time lecturer at a local technical college and was in the habit of using the firm's products as vehicles for this type of research.

Longer-term research may also take various forms and will often involve very close co-operation between university and firm.[9] Thus one Scottish firm hoped in 1968/69 to take on two Ph.D. students to work on various aspects of germanium/lithium crystal detectors and organic scintillators which would be directly related to their Ph.D. topics. In slightly different fashion, another firm was in the habit of supplying equipment, finance and know-how to a university laboratory and although this need not be directly connected with a Ph.D. degree it very often was. In another case it would be connected with the research of members of staff themselves.

As mentioned above the advantages to the firm lie in the possibilities of technical breakthroughs and in the possibility of future recruitment[10] of science and engineering graduates who have attained a working knowledge of the firm's interests and who will have had some experience of the equipment typically used by the firm. From the social point of view it will give the potential graduate fore-taste of the type of work he is liable to be doing later and consequently render him more immediately useful to his eventual employers. Many of the firms interviewed made the point that most graduates were fairly unproductive at the outset and that there was often a gestation period of up to a year before they were 'playing a full part' in the firm's activities.

There was a certain amount of selling to academic bodies although in

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[9] Although there were only eight cases of this.
[10] Unfortunately no definitive information was collected on recruitment.

most cases this was not an important section of their market. In the cases of firms manufacturing custom-built equipment (four in all - two in Scotland and two in England) there was inevitably very close technical interchange especially where the equipment was of a highly specialised nature. Thus one firm manufacturing a medical instrument designed to detect foetal blood flow in pregnant women has very close research contact with the Dick Vet. College in Edinburgh which is using one of these machines in its research.[11] It appears that this is an important avenue by which contacts are built up and maintained, usually on the level of personal friendship. Another avenue is the technical conference or symposium which attracts people from academic life as well as from industry and leads to fruitful relationships. In addition, of course, recruitment immediately puts a firm in touch with a variety of institutions.[12]

Localisation

I found in fact a marked degree of localisation although this varied with respect to the Scottish and English sub-samples. Of the eleven (out of fourteen) Scottish firms having contact with academic bodies all had contact with local academic bodies although these were not always their most important links. Eight firms had their most important contacts with local universities and of the others one had strong contact with a lecturer who had recently moved from a local university to one in England, while another, a subsidiary of a company based in the south of England, had more important contacts with Southampton and Birmingham universities. In most cases the localisation

[11] This is incidentally a good example of technical co-operation over a wide distance, the firm in question being situated in Hampshire.

[12] These contact sources were mentioned to me by research directors as the generally important ways by which contact is made and maintained.

narrowed down to the town or county in which the firm was situated. For example, firms in or around Edinburgh have their main contacts with the Heriot-Watt and Edinburgh universities, while in Glasgow the main contacts are with Glasgow and Strathclyde universities. One firm in Fife has its chief contact with St. Andrews University.

TABLE 4

SPECIFIC ACADEMIC CONTACTS (SCOTTISH SAMPLE)

Academic Body	Number of Firms having Contact
Strathclyde University	6
Glasgow University	5
Edinburgh University	3
Heriot-Watt University	4
Glasgow Art College	1
St. Andrews University	1
Paisley Technical College	1
Southampton University	2
Birmingham University	2
Manchester University	2
Oxford University	1
University of South Wales	1
Loughborough Technical College	1
Total number of contacts	30
Total number of firms	11

TABLE 5

SPECIFIC ACADEMIC CONTACTS (ENGLISH SAMPLE)

Academic Body	Number of Firms having Contact
Imperial College, London	6
Southampton University	4
Sussex University	1
Birmingham University	1
Bristol University	1
Edinburgh University	1
University of Surrey	1
Reading University	2
University College London	1
Manchester College of Technology	1
West Hamm College of Technology	2
Brighton College of Technology	2
Guildhall College of Technology	1
Colchester College of Technology	1
Chichester College of Education	1
Dick Vet. College Edinburgh	1
Total number of contacts	27
Total number of firms	13

In the English sub-sample, of the 13 firms (out of 16) who maintained links with academic bodies, 12 had contact with a local body. Again, narrowing down to particular areas, of the six (out of eight) in the Hampshire area, five had contact with a local academic body - viz. Southampton University, Portsmouth Technical College and Chichester College of Advanced Education - while of the six (out of eight) in

Berkshire and Sussex all had contacts with local academic bodies - the favourite here was Imperial College, London. In many cases firms had other academic links outside their immediate locality. This was true in particular of instrument establishments which sold to academic departments, although the most specialised of these - manufacturing digital equipment for student training - listed universities and technical colleges <u>within its own area</u> as its main regular contacts. It may be seen from Tables 4 and 5 that 25% (c. 19% England, 30% Scotland) of academic contacts were with bodies outside the areas within which the firms were located. The strength of this 'localisation' effect in the case of universities and technical colleges seems to indicate that a certain weight should be given to geographical factors in scientific communication although whether such factors represent a significant constraint upon flow of knowledge is still uncertain, since there were examples of firms who used facilities of universities well outside their immediate localities. An explanation for this may well lie in the fact that there tends to be a certain amount of specialisation in academic research and that in certain instances a firm may find it advantageous to maintain contact with an academic body some distance away. No systematic information, however, was collected on this point.

<u>The Scottish and English samples.</u>

Certain differences did arise between the two samples although, of course, how significant these differences are it is not possible to say. Eleven out of fourteen Scottish firms had contacts of some kind with academic bodies compared to the English experience of thirteen out of sixteen, and of these six of the Scottish firms' contacts were of more than minor significance[13] in the opinion of the research directors interviewed compared to four in English cases in two of which there were very strong user-supplier relationships. The total number of academic bodies in the Scottish sample with whom there was contact was 30 (2.1 per firm) compared with 27 in the English sample (1.7 per firm) and there were six examples of Scottish firms giving research projects to academic bodies whereas there were only two in the English sample. Now it will be seen in the section concerning government establishments that there is rather more contact with respect to the south of England than with respect to Scotland and it may well be the case that academic bodies are regarded as, to some extent, a substitute for government laboratories on the technical side. This trend appears especially with the highly specialised firms in the sample. In the English sub-sample only four firms had close contact on the technical side while the others, despite in many cases close contact with government bodies (see Section 3) had minimal contact with universities and technical colleges. Considering the specialist firms in Scotland this pattern did not assert itself and in the cases where there was close establishment contact there was also at the same time close liaison with academic bodies.

Summary and Conclusions

On the whole a certain amount of linkage was found between academic bodies and the sample of firms although the strength of this varied very much from firm to firm. It is difficult to generalise about firms which had little or no contact. Some were producing fairly standard pieces of equipment and could see little point in strong university contact while there were a number of examples of technologically very advanced

[13] See Table 3. In fact the assessment of 'strong contact' rested partly upon the subjective view of the interviewer as well as upon the assessment of the interviewee.

firms who had very little contact with universities. These firms tended to have close relations with government bodies.

The contacts that did exist did not in general depend upon sales although this is one factor in building up such contacts. Relating to this it became apparent that there are a number of ways in which these may be built up and fostered. Thus apart from sales, symposia, recruitment from universities and past friendships seem to be important.

On the whole direct use of library facilities did not figure greatly, the main uses being consultancies and test facilities. However, examples were forthcoming of firms which made a practice of undertaking co-operative research in a variety of guises. The Scottish firms were rather more active in this than the English firms. There did in fact seem to be marginally more contact with the Scottish firms than with the English firms and it may be that to some extent there is in Scotland a substitution of academic sources of technology for those of government establishments, although in many cases Scottish firms which had close university contact also had contacts with government establishments. There is also strong evidence of a localisation of contact in particular areas, so that mild support would seem to be offered for the geographical hypothesis outlined in ChapterIV.

3. Government Establishments

In this section the discussion centres around the relationship revealed between the firms in the sample and government establishments. As in the case with research associations and academic bodies an attempt was made to collect information on type and extent of contact, bodies with whom contact is made, localisation of contact, differences between the

Scottish and English samples. In addition particular attention was paid to the amount of development contract work done. As the investigation proceeded another dimension of importance came to the fore, viz. a close technical interchange of ideas, information and know-how arising out of and involved with the selling of products, sold by specialist firms to various government bodies. While this was not development contract work in the strict sense, it involved a considerable amount of user-supplier contact and was regarded as particularly important by the firms interviewed both from a commercial and technical standpoint.

It is difficult to categorize government establishments by type, but the following distinctions may be made for illustrative purposes.[14]

(i) National Establishments - formerly administered by the Department of Scientific and Industrial Research and now controlled by the Ministry of Technology. These bodies undertake research into problems directly related to national requirements. For example, the National Physical Laboratory (N.P.L.) in Middlesex is currently researching into problems of aerodynamics, autonomics, metallurgy, molecular science, chemical standards and a host of other disciplines each of which comprehends a number of sub-disciplines.

(ii) Departmental Establishments - these are administered by government departments and undertake research into various problems affecting the relevant departments. Of particular interest to this survey are the various 'defence establishments' since because of the markedly electronic nature of much of modern armaments we should expect these establishments to be particularly fruitful sources of ideas and know-how.

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[14] For further details on this and also on facilities offered see references in Appendix II.

Thus the Signals Research and Development Establishment (S.R.D.E.) in Hampshire is currently working upon satellite communications, modulation techniques, micro-electronic techniques and so on, as well as being willing to offer consultative services and test facilities to industry.

(iii) Research Council Establishments - for example the Agricultural Research Council (A.R.C.) controls several research stations which are currently working upon various problems such as drying and storing of crops, grain handling, improvements in agricultural and horticultural mechanisation.

(iv) Other - these include independent bodies, e.g. the Atomic Energy Authority (U.K.A.E.A.).

TABLE 6

CATEGORIES OF RESEARCH ESTABLISHMENT IN GREAT BRITAIN

		Total	Scotland	England
(i)	National (Mintech)	10	2	8
(ii)	Departmental*	44 (21)	5 (1)	39 (20)
(iii)	Research Council	142	27	115
(iv)	Other	8	0	8
	Total	204	34	170

*The numbers on brackets indicate 'defence' establishments.

In Chapter IV it was indicated that government establishments tend to be concentrated in the south and east of England. In particular it is argued that this concentration is even more marked since 56% of the Scottish stations do not appear to be connected with the electronics sector.[15] In addition it may be seen from Table 6 that only one of the 21 'defence establishments' is located in Scotland.

It is apparent that many of these establishments will be potential sources of technology to firms producing in the electronic field and most announce their willingness to offer consultative services, test facilities in ad ition to publishing technical reports on aspects of work done (see note 14).

Type and Extent of Contact

From Table 7 (below) it may be seen that defence establishments bulked large in the establishment contacts revealed in the sample. In fact these, plus the U.K.A.E.A., plus five national establishments (N.E.L., N.P.L., Warren Springs, Torrey, Forest Products) accounted for all but five of the English establishment contacts and all but three of the Scottish ones. Three of the six in the 'other' category were contacts with the U.K.A.E.A. It should also be noted that although the Research Council category appears low there were in fact two examples (1 Scotland, 1 England) of firms having contact with Medical Research Council (M.R.C.) stations. In these cases it was not possible to assess the number of stations involved.

As expected extent of contact varied from firm to firm. In general, however, it was fairly widespread, 24 out of the 30 firms interviewed

[15] 40% are A.R.C. stations, 12% are N.E.R.C., 4% are D.A.F.S. A further 26% are M.R.C. stations, the remainder consisting of the Road Research Laboratory (R.R.L.), National Engineering Laboratory (N.E.L.), Torrey Research Station, Naval Construction Research Establishment, The Royal Observatory and the Royal Botanic Gardens. No contact of any kind was maintained with the Naval Construction Research Establishment.

having some contact with government establishments, of these 18 having considerable significance for the firms involved.

TABLE 7

ESTABLISHMENT CONTACT BY CATEGORY OF ESTABLISHMENT[16]

	Total	Scotland	England
National	15	7	8
Departmental	41	13	28
- of which defence	(38)	(11)	(27)
Research Council	1	0	1
Other	6	1	5
Total	63	21	42

As in the situation with academic bodies use is made of specialised test facilities (12 cases), library facilities (7 cases) and consulting facilities (17 cases). In fact, however, by far the most important contacts seem to arise and depend upon selling to government bodies. This type of contact (technical inter-change) involves frequent meetings between firms and the staff of relevant establishments and is regarded as of particular importance not only from the point of view of dissemination of ideas, know-how, etc., but also because these firms rely to a large extent upon the government market. Hence, in addition to the contact necessitated by the custom-built nature of equipment it is important for these firms to keep up with the type of work being done and consequently with the type of equipment required. Contacts

[16] By 'establishment contact' contact with at least one firm in the sample is meant. A certain amount of confusion arises because of the fact that a few of the bodies with whom contact occurred consisted of more than one establishment. These were R.A.E., U.K.A.E.A. and M.R.C. This makes little difference either to the evidence here or the evidence on relative contact vis-a-vis Scotland and England.

of this kind stretching over a number of years have led to extremely close links in the cases of a number of English firms.[17]

A good example of this is that of an R & D department set up by two engineers who had previously been employed by the Royal Aircraft Establishment (R.A.E.).[18] Their original scheme was to undertake development into aerial photography mainly concerned with camera flight trials, since this was evidently going to be an important future market. However, it soon became apparent that the use of photographic equipment in the air involved certain engineering problems of vibration. Consequently an engineering section was added to complement the other development work and at this stage there was extremely close contact with R.A.E. stations at Farnborough and Appleforth since extensive testing and trials were necessary.

Many of the designs which were developed at that time are still essentially the basis for much equipment now used by government departments. In addition the engineering expertise built up enabled the firm to move into the manufacture of vibration test equipment which was (and is) sold to industry and universities as well as government bodies. This led to further contacts being built up with other defence establishments, such as the Admiralty Underwater Weapons Establishments (A.U.W.E.), the Admiralty Surface Weapons Establishment (A.S.W.E.) and the Fighting Vehicles Research and Development Establishments (F.V.R.D.E.), all of which are now important customers.

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[17] There were only two examples of Scottish firms falling into this category.

[18] Although this and the following are the only two examples of past connections with an establishment generating future contact (albeit in one case indirectly) it is interesting to note that this does in fact happen.

Another firm was set up by an engineer who had previously worked in R.A.E. and who recognised that there was a growing demand for certain data processing equipment which would feed information relevant to flight trials into a computer. Although this particular firm was originally set up in the United States it quickly set up a plant in Britain (Southampton) and for many years produced custom-built equipment mainly for R.A.E. and the British Aircraft Corporation (B.A.C.).[19] Over this period there were extremely close links with these organisations.

The above two examples are typical of those firms for whom the government market is of prime importance. There is, however, another (smaller) category of firms which sell less to the government market directly, but which nevertheless have very strong contact in respect of particular technologies. Thus one firm manufacturing scientific instruments sells to most of the large aircraft companies a wide variety of instruments (from de-icing equipment to Pitotstatic tubes, used for sensing air pressures and hence height and velocity of aircraft). One of its main contacts is the National Physical Laboratory which has considerable expertise in thermometry and with whom there has been very close contact in recent years. Another firm specialising in a variety of heating and thawing devices has had very close contact with the Torrey Research Station (into problems of thawing frozen fish using dielectric heating) and Forest Products Research Station (into problems concerned with the fast drying of wood, again using dielectric heating devices). It can, of course, be argued that these firms are

[19] Recently this firm was taken over by a computer company and now produces the appropriate hardware. However, even now about 30% of its output is sold to ministries and universities.

in a sense dependent upon the government market since in the former case the product will go indirectly to government buyers and in the latter case there will be orders from the establishments for equipment eventually produced. However, in both cases there will be commercial spin-off so that the reliance upon a government market is not so complete. It should be noted, of course, that as in so many aspects of this study the distinction mentioned is not an absolute one but is useful since it exemplifies the differing degrees of reliance upon a government market encountered in the study.

Overall, then, the pattern that emerges is one of contact as originally envisaged (i.e. technical facilities, consultancies, etc.) but for which the raison d'etre may be largely commercial. Put another way, many firms rely on government establishments as sources of technology, but they are also very much aware of the commercial advantages involved in maintaining these contacts.[20] Having said this, however, it is necessary to state that I did come across examples of contact more or less divorced from user-supplier contact.

Of the 18 firms with strong contacts, 16 fall into the categories discussed above, and of the two others (both Scottish) one has extremely close contact with a nearby laboratory on purely technical level while the other relies exclusively on development contract work. Of the six firms which have 'minor' contact with establishments, three use specialised test facilities, one has contact with A.S.W.E. in respect of a particular technique of relevance to their production, one has quality control contacts and one has an arrangement with R.R.E. concerned with the growing of optical crystals.

[20] In fact it proved impossible to seperate out these 'contact motives'. However, I am of the opinion that in many cases the commercial motive was stronger.

TABLE 8

NUMBERS OF FIRMS WITH ESTABLISHMENT CONTACT

Number	Total	Scotland	England
No contact	6	4	2
Contact with at least 1 establishment	24	10	14
More than 1 contact	16	5	11
'Strong' contact	18	7	11
Total firms	30	14	16

$\chi^2 = 7.14$ with 3 degrees of freedom. This is not significant at the 5% level, but is significant at the 10% level (see addendum on page 139).

Development Contract Work

By 'development contract' is meant a contract to undertake research and development into an instrument or system designed to fulfil some stated purpose. Such contracts are often 'farmed out' to industry as part of a wider project being conducted within the establishment itself. A distinction may be made between a 'development' contract and 'production' contract since a number of firms, particularly in the south of England, maintained that while they did no development contract work as such, they were selling and had sold a number of products to government bodies and that these products had involved a considerable amount of development effort. At the same time a pure development contract may lead on to (or may even involve) an order from a government body for a stated number of products arising from the research, in which case a certain amount of production is involved. Nevertheless a distinction must exist since all the firms interviewed seemed to know exactly what a development contract was although in some cases they denied that they did development contract work where I felt that this could well have been a correct description of the type of work done.

The distinction seems to be as follows - a contract is called a development contract where it involves research into a method of solving a particular problem, or the designing of a specialised instrument to solve this problem. It is a formal arrangement usually conducted in a series of 'stages' agreed upon at the signing of the contract, each stage being checked by a member of the staff of the establishment commissioning the contract. Production contracts on the other hand tend to be for products already developed. However, in many, if not all, cases adaptations have to be made to these so as to fit them for specialised uses and it is here that a lot of the technical interchange takes place. In certain instances what the firm called a production contract began to look very much like a development contract by the time the nature of the contract had been explained.

Ten out of the 30 firms did development contract work and all of the firms were fairly specialised and sophisticated. There was little difference here between the Scottish and English samples since in each case five firms were involved, although it was seen that rather more development work was done in the Scottish sample than in the English sample.[21, 22] However, this situation may be partly a reflection of the manner in which the respective samples were chosen.

Apart from profit the advantages to the firm may be categorised as follows:

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[21] Unfortunately adequate statistics on development contract work could not be collected. See Chapter V.

[22] In four of the Scottish firms development contract work was an 'important' part of their activities compared to three similar firms in the English sample.

(i) Funding of R & D which is directly relevant to the firm's activities and would in certain cases have to be done whether or not outside finance was available. Thus one Scottish firm mentioned that if it has an idea which it feels is of commercial value it will approach N.R.D.C., whereas if the idea is of purely military value it will approach a government department (or else an establishment directly).

(ii) Expanding the technology base of the firm into areas it might not have considered had it had to rely purely on internal funding.

(iii) As the thin end of the wedge into a government market. Thus one Scottish firm has done a small amount of development contract work for R.R.L. and maintained that the commercial factor was the main incentive here.

(iv) Becoming 'known' as a firm which does this type of work. This seems to be a rather important factor and several of the Scottish firms mentioned it. Thus one firm - a subsidiary of an English-based concern - maintained that they had had a great deal of difficulty in getting started since being successful in 'tenders' depended not so much upon the quoted price as upon 'known capability' to do the job,[23] and it is, of course, not easy to achieve 'known capability' unless you get a chance to prove yourself. What in fact happened in the case of this particular firm was that it built up certain personal contacts through its London office and in this way managed to acquire a few small

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[23] This is an interesting example of a feature of highly specialised industries like electronics which it would be foolish to ignore in any detailed study of it. Thus the sophistication of particular 'products' is such that there is a variety of possible 'qualities' of goods and that very often competition takes the form of technical sophistication rather than price. Hence the importance of some other criterion - in this case 'known capability' for judging the tenders of individual firms.

contracts to begin on. However, it is interesting that a well-known company moving into a new field should have this kind of uphill struggle to get going initially and that its eventual success in doing it was in some ways dependent upon personal contact. Another Scottish firm which is fairly active in the government contract business made the point that even now it found difficulty in acquiring these and that it was convinced that this was due to its distance from the relevant bodies. The firm was particularly interested in the small development contracts regularly put out by the U.K.A.E.A. which to this firm was a 'bread-and-butter' item. It maintained that these contracts tend to go to firms in the immediate environment of A.E.A. stations and it was largely due to this fact that the firm has recently conducted two mergers - one of which was a partial merger - with firms situated close to two of the most important A.E.A. stations, (Harwell and Aldermaston). Similarly another Scottish firm - a subsidiary of a large English-based company made the point that while it was interested in doing this kind of work, most of the relevant contracts were going to another division of the company in Bristol. In none of the corresponding English firms did either of these difficulties figure greatly, viz. difficulty of getting on to the bandwaggon and once on, staying there. I concluded from this that geographical distance did prove a certain handicap in winning this kind of work but that this handicap was not crucial and that where a firm was sufficiently interested a vigorous management would be relatively successful. Of the firms which did no development contract work, most were firms producing fairly standard pieces of equipment and did not have the necessary resources. However, there were examples of firms (mostly English) which had considerable contact with government laboratories, mainly on the level of technical interchange, and which were producing equipment of a fairly advanced type. These firms seemed to have no interest in development contracts although it seemed that this would be an advantageous way in which to fund a lot of the development that undoubtedly was performed.

One of the main factors here was that firms did recover development costs through sales and that where they were successful in doing this they saw little reason for tendering for development contracts. This was surprising since <u>a priori</u> it would be thought that a firm could not but gain having at least part of its R & D funded in this way, and also since there would certainly be some commercial spin-off. In fact various reasons were mentioned by research directors. One firm had done development contract work in the past and had made a 50% loss on the project since which time it had steered clear of this type of work. Another firm had in the past been involved but had found that there was little commercial spin-off, that outside control was too stringent, that the rate of profit was very low and that finally the fact that it was facing a growing market rendered it unnecessary for it to seek development contracts. A third firm manufacturing medical instruments and having close technical interchange with various M.R.C. stations had obviously never considered the possibility, although this firm, while technically advanced, had fairly cramped facilities. In general it became apparent that all of these firms were facing a seller's market and consequently had plenty of work to get on with. Thus with regard to certain other factors such as lack of commercial spin-off and low rate of profit it was not worth the while of these firms to tender for development contracts. It was noticeable, incidentally, that no English firm mentioned difficulties in winning these contracts and that all of them had close links with establishments on other levels.

There was a little evidence to show that firms may make some use of government establishments at an early stage in their activities in a particular field rather than later on. In terms of development contracts a very good example of this was a Scottish firm which recently moved into the field of micro-electronics. Having no knowledge of the field at all the firm began in two ways. First of all it negotiated a licensing agreement with an American company under which all technology implicit in existing products became available to it. At the same time it set up an R & D plant which relied completely upon development contracts and which had little connection with the production plant although the latter was situated very close by. The plan was that eventually the technical expertise gained by the R & D laboratory and the production expertise gained by the manufacturing establishment would enable the firm gradually to introduce its own products and become self-sufficient after a time. Presumably at that time the R & D laboratory will be intimately connected with production and will do a correspondingly smaller volume of development contract work. There were also three examples of firms in the south of England which had, in the past, built up expertise through contact with government laboratories (including development contracts) but had now either reduced, or were attempting to reduce, their reliance upon government markets. This was so for two reasons. First of all the rate of profit in the industrial market tends to be higher. Secondly too much reliance on the government market tends to place the firm in a weak position at a time when more firms are moving into the industry and when the market itself is contracting. However, it should be emphasised that the evidence for this is by no means conclusive, and that more research would have to be done before any meaningful conclusion could be reached.

Finally there is the question of sub-contracted work. Although specific questions were not asked on this subject it became apparent that a lot of this is done, both on the development and the production contract levels. Very often an order is made by a government establishment for a complete system usually to a large, well-established firm (e.g. Decca Ltd. and Marconi Ltd.) which in turn 'puts out' certain pieces of work to specialist firms. In cases like these the large firm acts to some extent as a general contractor buying specialist expertise in cases where it does not have the resources required to manufacture a component itself. A typical example was given by one firm. Thus R.A.E. might place a requisition order with, say, Marconi Ltd. for an automatic guidance system which will operate under certain specified environmental conditions. Marconi will in turn place an order (amongst others) with a specialised firm to produce, say, an 'isolator' of a given size and weight which will operate successfully under the specified conditions.

This pattern not only involves the specialist firm in close contact with the contracting firm but in many cases with the government establishment itself. One firm mentioned that it was through a contract of this kind that it had been able to build up extensive personal contact with the employees of a particular establishment.[24] To what extent this type of work is done I was unable to ascertain. (Even the firms themselves were not able to tell this), but that it must be a fairly important factor is certain since a number of firms mentioned that a proportion of what they sold to private industry went eventually to government outlets.

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[24] In this case the R.A.E. - the contract involved the use of their computing facilities.

TABLE 9

GEOGRAPHIC DISTRIBUTION OF GOVERNMENT CONTACTS

Location of contact / Location of firm		England	Sub-totals: S.E. other than Hamps.	Sub-totals: Hamps.	Sub-totals: Other than S.E.	Scotland	Percentage totals
English firms		40 (95.2%)	16 (38.1%)	19 (45.2%)	5 (11.9%)	2 (4.8%)	42 (100.0%)
SUBTOTALS	Other than Hamps.	24 (92.3%)	10 (38.5%)	9 (34.6%)	9 (19.2%)	2 (7.7%)	26 (100.0%)
SUBTOTALS	Hamps.	16 (100.0%)	6 (37.5%)	10 (62.5%)	-	-	16 (100.0%)
Scottish firms		14 (66.7%)	-	-	-	7 (33.3%)	21 (100.0%)

Localisation

It was noted in section 2 that there was evidence to support the hypothesis that firms in a particular locality will tend to have their strongest contacts with university departments in that area. The same picture emerges in the case of contacts with government establishments. In the Scottish sample, of the three establishment contacts which figured more than twice (N.E.L., R.A.E., and R.R.E.), N.E.L. figured six times, R.R.E. four times and R.A.E. three times. In addition one firm had close contact with the Road Research Laboratory at East Kilbride. In the English sample only two out of the 42 establishment contacts were with Scottish stations. One, with N.E.L., although important had been conducted entirely by letter while the other, with the Torry Research Station, had involved visiting.

Of the 42 English contacts, 35 were with establishments located in the counties of Hampshire, Sussex, Surrey, Middlesex, Kent, Berkshire, Hertfordshire and the City of London. Of these 19, or over half, were from Hampshire. Of the seven contacts outside this area, two were Scottish, three were with R.R.E. at Malvern, Worcestershire and two were G.C.H.Q. at Cheltenham, Gloucestershire. Considering the seven firms in the Southampton region[25] out of the total of 16 contacts, ten (or nearly two-thirds) were contacts with establishments in Hampshire itself. Five (or nearly one-third) were with R.A.E.

Thus it is clear that there is in fact a considerable degree of localisation here although it should be borne in mind that, as pointed out earlier in this section, the concentration of establishments in the south of England is such that we should expect a pattern of this kind to emerge. Nevertheless the fact that it should emerge so definitely (even the contacts with R.R.E. and G.C.H.Q. were easily within a day's journey from the firms concerned) suggests that geographical factors are important.

The Scottish and English samples

In the survey an attempt was made to determine whether there were any differences between the English and Scottish firms with respect to degree and type of contact. I also attempted to assess whether, in the opinion of firms, there were any disadvantages attached to geographical

[25] i.e. those firms located in area defined by a semicircle with radius 30 miles from Southampton as the centre. We are here considering firms with at least one establishment contact.

distance from the relevant establishments.

Of the 14 Scottish firms 10 had contact with government establishments, and of these seven were judged to be 'strong' contacts by the research directors interviewed. Of the 16 English firms, 14 had contact with establishments and of these 11 were strong contacts. The total number of 'establishment contacts' was 21 (2.1 per firm) in the Scottish case compared with 42 (3.0 per firm) in the English case, while the number of strong establishment contacts was 12 (1.2 per firm) in the Scottish sample compared with 35 (2.5 per firm) in the English sample.[26]

While the results suggest that in terms of testing facilities and library facilities there is little to choose between the two samples the situation regarding consulting seems markedly different. 12 of the 14 English firms had consultancy arrangements of some type compared to five of the ten Scottish firms and it is here that the difference hinted at in the above paragraph seem to arise. Most of these consultancies arise as part of the technical interchange mentioned above.[27] In fact 11 of the 12 English firms fall into the category of firms which have close technical interchange with establishments either on the basis of direct selling or on the basis of 'getting in'

[26] This should be treated with caution. In assessing the 'strength' of contacts I relied partly on the opinion of the research director and partly on my own judgment. Where the contact involved no more than the occasional use of a facility then it was treated as of minor significance. Also it is possible that some firms did not give a complete list of establishments. This was more likely to be the case with the larger and technically more advanced firms who had contacts with many establishments. I felt that at times the more 'standard product-type' firms were racking their brains to think of establishments and although I attempted to take this into account it is possible that I may not have been completely successful.

[27] Of the three which do not, two are Scottish firms.

to a particular government market. Five of the ten Scottish firms fell into this category. All of these are technically advanced firms. Two are divisions of internationally known English-based firms while the other three are smaller firms. Each of the latter mentioned that they had experienced difficulties in maintaining marketing contact in the south of England and each seemed to have very close technical contact with local universities. In the cases of the former two, one relied completely on development contract work while the other claimed that the bulk of its market was public.[28]

As noted above, eleven English firms claimed 'extensive' contact with establishments on a user-supplier basis involving technical interchange. It was apparent, however, that this varied from firm to firm. In some cases contact was less strong than it had been in the past at a time when most of the fundamental development of their products took place. In other cases government markets claimed the smaller proportion of the firm's total output.

With regard to development contract work there was little to choose between the samples. Certainly the Scottish sample was no worse off than the English sample. A number of English firms had in fact done this type of work in the past but had stopped this for a variety of reasons. No Scottish firm fell into this category.

Overall the English sample had more contact than the Scottish sample

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[28] There is evidence that the first one experienced certain disadvantages due to its distance from the relevant establishments. The second company, unfortunately, was not willing to give full co-operation in the survey so that its information is sketchy.

but this seemed to depend fundamentally upon commercial considerations. In fact with regard to user-supplier contracts four of the five pertinent Scottish firms experienced some difficulty in keeping these up whereas no English firm mentioned this problem.

Summary

Overall the amount of contact revealed by the sample of firms seemed to be rather greater than that with universities although this may be due mainly to the importance of government establishments as markets (directly or indirectly) rather than that of their greater technological capacity. This 'technical interchange' involves frequent meetings and is a necessary counterpart of sales activities. More of this type of contact seemed to take place in the English sample than in the Scottish sample partly because of the greater number of firms involved and partly because of difficulties due to distances. In general there was more establishment contact in the case of the English sample.

There was also evidence that firms will tend ceteris paribus to have contact with establishments in their own area, thus giving weight to the geographical hypothesis mentioned in Chapter IV. There was little difference in the amount of development contract work done between the two samples. In fact generally the amount of direct work of this kind seemed to be surprisingly small. However, there was a certain amount of confusion as to the difference between a development and a production contract and it may be that in strictly economic terms more development contract work is done than was revealed in the survey, especially in the case of the English sample.

Finally it is noted that the bulk of establishment contacts were with 'defence',establishments, 'national' establishments and the U.K.A.E.A. Contact with research council establishments and those of 'civil' ministries were few and far between.

4. Library, Information and Other Contacts

This section is split into three parts. First of all I shall consider the use made of library and information services by the firms in the sample. Secondly, I shall consider the various other types of contact not previously looked at but which I felt might need to be examined in a complete analysis of the general problem. Thus in the questionnaire certain questions were asked regarding attendance at conferences, secondment, etc., which were intended to give a clearer picture of the overall strength of contact (see Appendix I). Finally I shall consider the role of other private firms as alternative sources of technical expertise paying particular attention to the uses made by subsidiaries of various facilities offered by the relevant parent companies.

Two points should be noticed here. First of all strong reliance is placed upon answers to the questionnaire in parts of sections I and II.[29] Unfortunately, however, despite follow-up letters five questionnaires for the English sample were not returned and although I have in places filled in information from the interview transcripts, it has not been possible to do this for the majority of the relevant questions. Secondly, especially in section (b) certain points will be discussed which emerged during the enquiry but which were not specifically included in the original survey framework. This follows the strategy outlined in Chapter V whereby the research strategy was deliberately left open-ended in order to pick up unanticipated facets of the relationships. I took the view that in an area as diffuse as this, while

[29] See Appendix I.

it was possible to ask concrete questions in certain areas, there would inevitably be important facets revealed as the survey progressed. This is, in effect, what has happened so that the discussion in section (b) of this section - as well as that in parts of the previous section - is not as conclusive as might be desired.

(a) Library and Information Services

It was decided that the survey should include an investigation of the use made, by the sample of firms, of these services with regard to:

(i) the particular services used,

(ii) the extent of use,

(iii) localisation of use,

(iv) differences between the Scottish and English samples.

Libraries

Of the 22 firms from whom information was elicited (by questionnaire), 18 (86%) possessed their own technical library, although this was usually fairly small. Ten out of the 18 firms possessing libraries had libraries containing around 100 books and only in one case - a very large Scottish firm - did any plant library contain more than 400 books. All of them, however, contained a large volume of 'trade' journals. Of the four firms which had no library, one (the only Scottish example) made extensive use of that of its parent company (situated 40 miles away) and also libraries of two research associations of which it was a member through its parent company. Of the other three, two, viz a firm manufacturing high-technology digital equipment for universities and a firm manufacturing a standard type of component, made no use of any alternative library source although both made use of various information services located in their area. The third, manufacturing mainly for a government market, made 'frequent' use of government establishment libraries. It also made use of three different information services as well as relying upon the various professional institutes (see below).

TABLE 10

LIBRARY CAPACITY

Number of books (to nearest 100)	Total (18 firms)	Scotland (12 firms)	England (6 firms)
< 50	1	1	0
100	10	5	5
200	3	2	1
300	2	2	0
400	1	1	0
450	1	1	0

χ^2 = 9.00 with 2 degrees of freedom. This is significant at the 5% level (see addendum on page 139).

With regard to use of outside library facilities, 20 firms (11 Scottish, 9 English) replied to question II (xii) in the questionnaire (see Table 11). Three firms made no use of the library sources categorized in Table 11. Of these (all English firms), two had no internal library while the third made use only of outside information services but had its own internal library. As can readily be seen, use made of outside library sources was not extensive and only in the category of public libraries did more than 50% of the respondent firms make use of the facility. Even here three-quarters of the firms making use of the facility described it as 'sporadic'. If we give weights of three points, two, one, zero respectively in terms of frequency of usage we

TABLE 11

EXTENT OF USE OF VARIOUS LIBRARY SOURCES

(NUMBER OF FIRMS)

	Very frequent	Frequent	Sporadic	Nil	Total firms
N.L.L.					
Total	3	3	3	11	20
England	1	2	2	4	9
Scotland	2	1	1	7	11
Aslib					
Total	0	1	2	17	20
England	0	0	0	9	9
Scotland	0	1	2	8	11
Academic					
Total	1	0	7	12	20
England	0	0	1	8	9
Scotland	1	0	6	4	11
R.A.s					
Total	2	0	4	14	20
England	1	0	1	7	9
Scotland	1	0	3	7	11
Govt. Est.s					
Total	1	2	4	13	20
England	0	1	2	6	9
Scotland	1	1	2	7	11
Public					
Total	1	2	9	8	20
England	0	0	4	5	9
Scotland	1	2	5	3	11

get a situation outlined in Table 12.[30] It may be seen from this that most use seems to be made of the National Lending Library (N.L.L.) at Boston Spa and the various public libraries within easy reach of the firms themselves, although even here the average extent of usage is rather less than it would be if all firms made 'sporadic' use of the facilities offered. Very little use is made of Aslib (none in the case of English firms),[31] and there seems little to choose between academic bodies - i.e. universities and technical colleges - and research associations. This incidentally gives a good idea of the total use of research association facilities compared with those of other outside bodies since it was pointed out in section 1 that the main use made of research associations was that of library facilities.

It may also be seen that the Scottish firms are rather more active in this context than the English firms. Thus in all categories save one, 'intensity of use' is greater in the Scottish sample. Even in this one case (N.L.L.) the difference is only one of 9%. The biggest differences seem to be with respect to use of academic bodies and Aslib (although see note 31 below). This seems to bear out the conclusion reached in section 2 that more use is made of academic bodies in the case of the Scottish firms. It would appear, therefore, that there is no evidence to suggest that Scottish firms suffer any disadvantages with respect to the availability of library facilities.

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[30] Needless to say it would be unwise to read too much into these calculations and they are only included for illustrative purposes. To begin with they pertain to only two-thirds of a small sample of firms. Secondly the weights themselves are arbitrary although the weights used (i.e. 3, 2, 1, 0) seemed the only reasonable ones.

[31] In fact one English firm subscribed to Aslib. In this case the completed questionnaire was not returned.

TABLE 12

INTENSITY OF USE OF LIBRARY SOURCES

	Intensity of use	Intensity if all firms make 'frequent' use	Intensity of use (%)
N.L.L.			
Total	18	40	45
England	9	18	50
Scotland	9	22	41
Aslib			
Total	4	40	25
England	0	18	0
Scotland	4	22	18
Academic			
Total	10	40	25
England	1	18	6
Scotland	9	22	41
R.A.s			
Total	10	40	25
England	4	18	22
Scotland	6	22	27
Govt. Est.s			
Total	11	40	28
England	4	18	22
Scotland	7	22	32
Public			
Total	16	40	40
England	4	18	22
Scotland	12	22	55

χ^2 = 24.65 with 3 degrees of freedom. This is significant at the 1% level (see addendum on page 139).

One explanation of the less frequent use made of the specified library facilities may lie in the fact that there are other sources of information. Indeed it became apparent as the survey progressed that a number of firms made use of the libraries of the various professional institutes (in particular the Institute of Electrical Engineers, I.E.E.) by virtue of the membership of certain of their employees. In fact five firms (four English) mentioned these institutes as important sources of library material. In addition another English firm mentioned that it made extensive use of the Science Museum Library, administered by the Department of Education and Science (D.E.S.). It should be emphasised, however, that no specific question relating to professional institutes was asked and that the above firms volunteered the information in response to a general question. Consequently it may well be that rather more firms may make use of these bodies especially since staff membership seems to have been fairly widespread amongst the firms sampled.

Information and Abstracting Services

In addition to library facilities the use made of information services was considered. This category should be taken to include all information sources apart from sources of books and periodicals. Thus abstracting services, technical bulletins, indexes to technical sources and other documentation facilities come under this heading. Two points should be noted here. First of all the distinction between 'libraries' and 'information services' is be no means hard and fast. Thus, certain 'bulletins' may be borrowed from libraries as well as books. However, I felt it worthwhile to make the distinction as one by which libraries are used for borrowing purposes, whereas information services supply literature 'for keeps', either as a paid service or as a free service connected with a related company or public body. Secondly, and connected with the first point, many of the library sources discussed above also supply information services. It does not follow, of course, that a firm making use of the one must necessarily make use of the other.

TABLE 13

FIRMS USING INFORMATION SERVICES

	Total	Scotland	England
Number using > 1	8	2	6
Number using at least 1	20	11	9
Number using none	5	2	3
Total number of 'information' contacts	33	13	20
Total number of firms	25	13	12

It is apparent here that in terms of numbers of 'information contacts' use of information services, as in the case of library facilities, is fairly general. Thus 80% of respondent firms use at least one information service while 40% of these use more than one. The total number of 'information contacts' per firm is roughly 1.3. There appears a certain difference between the Scottish and English samples insofar as the English firms are rather more active in this respect than the Scottish firms. Thus, although a larger proportion of Scottish firms have at least one 'information contact', a very much smaller proportion have more than one such contact, and the total number of 'information contacts' per firm is 1.7 in the English sample compared with 1.0 in the Scottish sample.

TABLE 14

SPECIFIC INFORMATION CONTACTS

	Total	Scotland	England
Research Associations	4	2	2
Government Establishments	1	1	0
Professional Institutes	6	2	4
Private	7	1	6
Parent company	5	4	1
N.L.L.	2	0	2
N.R.D.C.	2	1	1
Mintech Bulletins	4	2	2
Science Museum	1	0	1
U.K. R&D reports	1	0	1

χ^2 = 4.00 with 2 degrees of freedom. This is not significant at the 5% level (see addendum on page 139).

From Table 14 it may easily be seen that there is a wide variety of information sources used by firms. At the same time, however, it is not possible to isolate particular sources as being of prime importance. A certain amount of localisation is evident since in the case of 'private' contacts, all are with local bodies. However, this must only be considered as slight on the basis of the available evidence. In addition, apart from the category of parent companies and private sources, little can be said about the separate Scottish and English samples.

Overall, however, there does seem to be rather less contact in the case of the Scottish sample although the difference is not marked. It is significant perhaps that 31% of the respondent Scottish firms felt that geographical distance from the various relevant information sources affected the extent to which they used them, compared with 11% of the English firms.

Two final points should also be made. First of all the conclusions on the <u>extent</u> of use of information services have been reached without regard to the extent of use of each particular service (i.e. how important each was regarded to be, annual cost, amount of information, etc.). While this may have made some difference it was felt that to assess this would have required a full-scale enquiry on its own. Secondly and relatedly the whole question of retrieval, storage and dissemination of information, its efficiency, supply, demand, etc. is a very large and involved one indeed. Thus, while it was necessary to probe a certain distance I did not have the resources necessary for a full-scale investigation.

(b) <u>Other Contacts</u>

In this section consideration is given to questions II (xvi) to (xx) of the questionnaire (see Appendix I) relating to other types of contact not previously considered.

Questions were asked on attendance at conferences, secondment to and from outside research bodies, consultation by research bodies concerning value of proposed research, the referral of particular research problems to outside research bodies and other forms of contact. The responses to these questions are outlined in the tables below. The data here refers to questionnaires from 22 firms (13 Scottish, 9 English) unless otherwise stated.

TABLE 15

ATTENDANCE AT CONFERENCES DURING 1967

	Total(21)	Scotland(12)	England(9)
Number of conferences attended per firm	5.1	4.3	6.0

Attendance at conferences seems to be fairly widespread. The Scottish sample were asked what their assessment was of the value of these conferences and, although not all replied, the general concensus seems to be that their main value lies in keeping firms abreast of general developments in a particular field,[32] rather than as direct indicators of new technical possibilities. A few examples were given of personal contacts made at conferences which have since proved valuable to the firms concerned. Table 15 indicates that the English sample is on the whole rather more active than the Scottish sample. In addition all the English firms had attended at least one conference in 1967 whereas two Scottish firms had not. One of the latter mentioned that most conferences were held in and around London and that were they sited more centrally it would certainly make a practice of sending members of staff to relevant functions of this kind. There were, however, examples of Scottish firms attending large numbers of conferences, some of which were held overseas. Therefore, I conclude that while locational factors may place Scottish firms at a marginal disadvantage, this disadvantage is not a serious one.

[32] In view of the response rate and the haziness of replies I did not feel it worth while to ask the same questions of the English sample.

In the report of the Zuckerman Committee on the management and control of R & D,[33] made on behalf of government departments, the committee recommended inter alia that before selecting civil research projects, establishments should have as wide a knowledge and awareness of the research needs of industry as possible. In particular they recommended the practices of secondment and consultation with industry as being necessary inputs in the decision-making process. They felt that at that time there was too little attention paid to the relevance of national research to industrial activity and that closer co-operation was desirable.

TABLE 16

SPECIFIC CONTACTS WITH OUTSIDE RESEARCH BODIES

(Number of firms with at least some contact)

Question	Total	Scotland	England
(xvii) Consultation on particular projects	4	2	2
(xviii) Secondment to	5	3	2
(xix) Secondment from	2	2	0
Total firms questioned	22	13	9

In the light of this three related questions were put to the sample of firms. Each of these questions dealt with the experiences of the sample over the last five years with research associations and government establishments and are listed in Appendix I (Questions II, xvii-xix).

33. 'The Management and Control of Research', (London, HMSO, 1961).

Little can be said about the separate samples apart from concluding that Scottish firms seem to be no less represented than English firms. However, it is interesting to note that the overall contact <u>over the last five years</u> is very low indeed in each category (i.e. secondment to and from outside research bodies, consultation on attitudes to particular projects). Why this is so is uncertain. It may be that since the bulk of development contracts tend to go, at least initially, to large firms it is with these that most consultation is done. Again it would be understandable if small firms took the view that they could not spare their development staff even for short-term secondment especially as contact with government establishments on other levels may serve the same purpose. It would appear that this type of contact would be a suitable area for further research in the light of the recommendations made by the Zuckerman committee.

TABLE 17

REFERRAL OF SPECIFIC RESEARCH PROBLEMS TO OUTSIDE RESEARCH BODIES, 1967

	Total		Scotland		England	
	Firms	Problems	Firms	Problems	Firms	Problems
Academic bodies	5	18	3	6	2	12
Government est.	3	8	2	3	1	5
Research ass'ns	5	9	3	6	2	3
Total firms	22		13		9	

χ^2 = 10.52 with 2 degrees of freedom. This is significant at the 1% level (see addendum on page 139).

Finally firms were asked how many problems of a research nature they had given to the three categories of outside research bodies in 1967. It does not appear that there is very much contact of this kind. Nor does there appear to be much difference between the Scottish and English samples. Again it is not certain why this is the case, although a number of firms mentioned that they would not in general refer problems of this nature because of 'commercial pressures'. They implied by this that outside research bodies were not operating within the same time horizons and that where possible they would attempt to solve it themselves or use some other technical source.

The only distinction between the Scottish and English samples lies in the number of problems referred to academic bodies which is greater in the English case. While this does not appear to agree with the evidence adduced in Section 2, the following points should be noted. Firstly ten of the twelve problems noted were referred by a firm which specialises in advanced digital and analogue equipment, for university teaching purposes, has at least one part-time member of a university staff, and in general has extremely close contact with academic bodies. Secondly, a number of the 'research projects' mentioned in Section 2 were not strictly 'problems of research nature' but were very often projects of an open-ended nature designed for student training and possible new insights in a particular area of technology. Finally this question dealt with one particular year, 1967, whereas the evidence cited in Section 2 was of a more general character and referred to the 'practice of giving research projects'. In fact this question was designed to elicit the extent to which firms use outside research bodies to solve problems of a more immediate and applied nature which are a significant constraint upon the firm's activities in the short term. Predictably the use here seems fairly small.

(c) Private Industry

A study of this kind would not be complete without some reference to the role of private industry in the production and dissemination of R & D and other technical facilities. Although this sector was not investigated as such, a number of instances arose during the survey of situations where private industry was regarded as an important source of technical expertise. Thus of the 22 firms (13 Scottish, 9 English) responding to this question, seven maintained that they make use of private contract R & D facilities (5 Scottish, 2 English). These facilities are provided by certain firms which either specialise completely in this type of work or else have extensive R & D facilities which they are willing to hire out.

64% of the firms interviewed (83% Scottish, 50% English) volunteered the fact that they made at least some use of facilities provided by private organisations.[34] These contacts comprised computing facilities, testing, consulting, information services and a variety of other less formalised contacts varying from receipt of trade literature and user-supplier relationships to personal contacts. It is heavily emphasised, however, that this section is based largely upon information revealed from the interviews conducted which was not specifically sought at the outset. In no sense is a complete analysis of this type of contact made. Consequently Tables 18 and 19 have been included purely for illustrative purposes and do not include a number of more informal contacts (e.g.

[34] These contacts do not include 'trade journals' but the use of facilities of parent companies has been included.

TABLE 18

NUMBER OF FIRMS HAVING CONTACT WITH PRIVATE ORGANISATIONS*

	Total	Scotland	England
Number of firms	18	10	8
Total number of firms interviewed	28	12	16

*These include contacts with affiliated companies

TABLE 19

TYPES OF CONTACT WITH PRIVATE ORGANISATIONS*

Type of contact	Number of contacts		
	Total	Scotland	England
Contract R & D	7	5	2
Testing	2	0	2
Library and Inf. services	12	5	7
Co-operative research	2	2	0
Manufacturing under licence	8	3	5

*These include contacts with affiliated companies trade literature) which undoubtedly exist. Indeed it is almost certain that all firms in this sample have at least some contact of a technical nature with private industry.

What can be said, however, is that many of the technical services offered by the outside research bodies investigated in this survey are also offered by private organisations and that use of these latter facilities was found to be fairly widespread among the sample. Indeed a number of firms mentioned that in specific instances they would prefer to consult a private industry.

Finally a word about relationships with affiliated companies. As pointed out in Chapter V , the Scottish and English samples were constrained by choosing the same proportion of 'subsidiaries' of overseas companies. In fact, of the 30 firms sampled 17 (9 Scotland, 8 England) were affiliated to other private companies and in one case (Scottish) a 'parent' company was sampled. Ten of these were subsidiaries of U.S.-based companies (4 Scotland, 6 England) while the remainder were affiliated to other companies in the United Kingdom. One company is affiliated to companies in the U.S. and the U.K.

The subsidiaries of U.S. companies were set up originally as sales and/or manufacturing outlets for products developed by their respective companies. All, however, now possess their own development staffs and produce their own products although many still fulfil their original roles. I found in fact that there was a considerable amount of information flow from 'parents' to their respective subsidiaries, taking the form of data sheets, technical reports and so on. It was not possible, however, to measure the extent of this information flow, its value, or whether it amounted to an alternative to other sources. The relationships of the seven firms affiliated to companies in this country seem very much more tenuous. There was only one example of close contact, and in this case the subsidiary was located within 40 miles of its parent. In three cases the relationship seemed only financial and in the other casesthe technical contact seems to have been slight.

Summary

There was fairly wide usage of library facilities and information services of one form or another. Most firms possess their own technical library and most make use of some form of outside library facility althoughthe extent of this does not seem to be very large. There is a wide variety of information service used by firms. There was some evidence of localisation of contact and the Scottish firms seemed to make rather less use of outside information services. However, this need not be significant since eleven Scottish firms used at least one information service and this did not include 'trade journals' which are very widely used. Scottish firms did not make any less use of outside library facilities.

In terms of 'other contacts' discussed in Section (b) there was very little secondment either to or from outside research bodies, but attendance at technical conferences seems to be fairly widespread. With respect to referral of short term research problems, there is little overall contact, the main reason given being shortage of time in relation to the 'pressures' of commercial life. In each of the 'other contact' categories there was little difference between the Scottish and English samples.

Finally there was widespread use of private sources of technology although it was not possible to give a quantitative assessment of the strength of this contact. In particular, subsidiaries of overseas companies were very often in receipt of technical information from their parents.

CHAPTER VII

CONCLUSIONS AND SUGGESTIONS FOR FURTHER RESEARCH

(1) Chapters II and III concentrated upon building up a theoretical picture of the relationship between scientific and technological advance on the one hand, and industrial production on the other. Specifically the following points were made:

(i) It was suggested that, while the evidence linking investments in innovative activity to economic growth does not appear to show a very positive causal influence from the former to the latter, technological change can play a very significant role with respect to the competitive position of firms within particular industrial sectors.

(ii) This emphasis upon the competitive role of technological change implies that if there are factors at the region level inhibiting the effective use of new technologies by industry, then certain regions may find themselves at a disadvantage in attaining rapid economic and social development. The question was asked: what might these factors be?

(iii) A certain amount of evidence exists which points towards geographical 'clustering' of public and semi-public research institutions (the scientific infrastructure), institutions which act as potential and actual sources of new technologies. Also a certain amount of more limited evidence exists to support the contention that the scientific infrastructure will attract science-based firms to its own location. These two factors give an <u>a priori</u> basis for suspecting that technological communications may be affected by geographical distance.

(iv) More specifically, it was hypothesised that geographical distance from the scientific infrastructure will affect: (a) the cost of acquiring new technologies - interpreted broadly in order to include costs attributable to technological factors which have to be incurred in putting products on the market; (b) knowledge of what new technologies are available. These hypotheses were couched in terms of a theoretical analysis of cost differences arising out of differential access to technology sources.

(v) In addition it was pointed out that the techno-economic relationship between industry and the scientific infrastructure is a very complex one, since the concept 'technology' subsumes a wide variety of different technological elements. A delineation was made of these elements and the following implications were mentioned:

(a) Different industries would be likely to exhibit varying patterns with respect to the use of outside technology sources, depending fundamentally upon their different 'scientific receptivities'.

(b) Due to the essential discontinuity between the various elements of appropriate technology and different industrial products, scale factors will operate such that the 'attractive power' exercised by the scientific infrastructure will be greater, the wider the variety of technological disciplines represented. From the point of view of expanding science-based industry in a region this would appear to argue in favour of setting up a <u>complex</u> of appropriate outside research bodies.

(c) Large firms might be expected to rely less on outside technology sources than small firms.

(d) The differential costs, mentioned above, would vary for different technological elements.

(vi) Finally, it was emphasised that there is no presupposition in favour of regarding technological factors to be more significant than other factors known to be operational in industrial location.

(2) With these points in mind the Scottish economy was examined as a relatively underdeveloped region within the wider U.K. national economy. It was shown that Scottish industrial structure has traditionally been biased in favour of sectors which exhibit low rates of growth and which are not highly receptive to advances in new technologies. Indeed even within industrial sectors there is a certain amount of evidence pointing towards a poor research and development performance. Conversely many of the newer industries such as aircraft, telecommunications and electronics have, for a variety of reasons, tended to locate in the south-east and midlands of England. At the same time there exists a strong concentration of outside research bodies in the south and east of England and much of the Scottish scientific infrastructure consists of institutions whose activities would not, it is thought, be related significantly to modern industrial advances.

(3) In the light of this discussion two general hypotheses seem to emerge: viz. <u>that geographical distance from research institutions significantly inhibits the ease with which private industry may maintain contacts with these institutions and that this will be reflected in the extent of contact actually made</u>. If this hypothesis is supported, a related hypothesis emerges: viz. <u>that this situation has a significantly deleterious impact upon the effective research capacity of science-based industry in Scotland and consequently upon the rate of growth of Scottish science-based industry</u>. These hypotheses may be called hypotheses 1 and 2 respectively.

These hypotheses were, in consequence, made the focus of a study on a small sample of Scottish firms in the electronics industry, taking as a 'control' a corresponding sample of English firms located in the south of England. At the same time an effort was made to achieve greater insight into the nature of the techno-economic relationship between the scientific infrastructure and industry, in terms of the form these contacts take, their relative importance, and which particular sectors of the scientific infrastructure are most often used. Two points should be born in mind. First of all the conclusions pertain only to the electronics industry and even here the sample is a small one. Clearly an examination of other industries might produce quite different relationships. Secondly, because of the qualitative nature of the analysis the judgement as to whether or not the conclusions are significant does not rest upon valid statistical laws, and consequently the conclusions drawn should be regarded as indicators of possible tendencies rather than as tendencies in themselves. It is, of course, hoped that the issues and points raised in this thesis will be the object of further research.

(4) Results:

(i) There was strong evidence that contact with outside research bodies tends to be 'localised'. This was particularly evident in the case of academic bodies, but the same general picture emerged with government establishment contact. It also appeared to a certain extent with regard to the use of outside library and information services. Very little evidence of localisation was found in the case of research association contact. However, overall contact with research associations was so low that little weight is given to this.

(ii) As mentioned above overall contact with research associations is small. 60% of the firms in the sample had no contact of any kind, there being no appreciable difference between Scottish and English firms in this respect.

(iii) There was widespread contact with government research establishments, and this was heavily concentrated on contact with 'defence' establishments, five 'national' establishments and the U.K. Atomic Energy Authority. Contact with Research Council establishments was very small. Government establishment contact was greater with the English sample than with the Scottish sample. This may be due to a greater amount of user-supplier contact, government establishments being regarded primarily as markets (or as vehicles into markets) rather than as sources of technical expertise, as such. Of course, it is very difficult to separate the factors out, and a number of examples were found in the English sample of purely technical contact having nothing directly to do with commercial considerations. Nevertheless the stress laid by research directors upon 'technical interchange' leads to the conclusion that market considerations may largely account for the difference in contact between the Scottish and English samples.

(iv) Development contract work played a different role with each firm depending on its maturity and reputation within the industry. While many of the English firms no longer placed as much importance on the securement of development contracts, the interviews suggested that development contracts were easily secured, and had played a significant role in the early stages of the firm's growth. On the other hand, Scottish firms had stressed the difficulties they had encountered in securing development contracts in the initial instance. This would suggest that firms located in Scotland were at a disadvantage in securing the development contracts which had played such an important role in the initial growth stages of the established firms. The additional difficulty experienced by Scottish firms in obtaining development contract work is probably partly due to the increased distance from government establishments. However, it could equally be due to the lesser experience and reputation of firms in the Scottish sample.

Thus, the fact that the Scottish sample enjoyed a slightly larger number of development contracts in proportion to the English sample is not in itself to be regarded as evidence of superior or even equal access to technical knowledge on the part of the Scottish firms. Taken by itself this might have suggested that Scottish firms were not at a disadvantage compared to English firms, but when evidence on the role of the development contracts is taken into account the opposite view seems to emerge.

(v) Contact with universities and technical colleges was found to be fairly widespread, and there was rather more contact in the case of the Scottish sample than with the English sample. This would seem to point to the operation of a substitution effect. Thus there may be a tendency for Scottish firms to rely rather more upon academic bodies and rather less upon government research stations as sources of technology and that this may be at least partially due to geographical considerations.

(vi) Most firms possessed their own technical library and most made use of outside library facilities, although this was not extensive. The Scottish sample made rather more use of outside library facilities than the English sample and this was particularly marked with respect to use of university and public libraries. Both of these latter sources were generally situated in the same geographical area as the firms.

(vii) There was also widespread use of a variety of information services. In this case the English sample were rather more active than the Scottish sample. This is probably due to the greater concentration of information services and professional institutes in the south of England than in Scotland. However, it should be recognised that all firms receive a variety of 'trade journals' which may to some extent fill the 'information gap' experienced by Scottish firms.

(viii) As regards 'type of contact', very little can be said of a specific nature because of the haziness of some of the replies to the questionnaire. Research associations, insofar as they are used, are chiefly used as sources of literature, although examples were found of problems of a short term nature being given to them. The most important type of contact with government research stations is that of technical interchange of ideas, know-how, etc. arising through marketing activities. Very little use seems to be made of outside computing facilities and the practice of secondment to and from outside research bodies is not common. Nor did very many examples occur of consultation of firms by government establishments and research associations in respect of research projects being considered by the latter.

(ix) The practice of attending conferences of a technical nature is fairly widespread, the English firms being rather more active than the Scottish firms. This may be partially a reflection of the tendency for these conferences (particularly those organised by professional institutes) to be held outside Scotland.

(x) Finally it should be noted that private industry (particularly parent companies) acts as a source of technology in a variety of ways and so can be regarded as an alternative source of technology to the outside research bodies considered.

(5) It seems to follow from the results listed above that scientific and technological activity have definite regional characteristics, thus

(5) The importance of technical interchange in the marketing of products [see (4)(viii)] adds a possible extra dimension to the relationship between industry and the scientific infrastructure. Thus in addition to the "normal" advantages experienced by firms located close to sources of technical excellence [e.g. access to research results, scientific services etc.], it would appear that there are further factors of a marketing nature which require close contact between buyer and seller. This has two aspects to it:

(a) When a firm is selling directly to the scientific infrastructure it will normally require to interact fairly closely with the infrastructure from the point of view of ensuring that the product meets the required specifications. This factor plus the high technical sophistication of many of these products can often mean the necessity for frequent and close user/supplier contact involving detailed discussions of applications engineering. It is suggested, hypothetically, that this feature of the relationship would place those firms located close to the scientific infrastructure at an advantage compared with those firms located further away.

(b) Secondly, it would appear that there are distinct marketing advantages associated with close contact between firms and the scientific infrastructure [mainly with government establishments], not so much in terms of selling <u>directly</u> to establishments but rather in terms of using establishments as an entry into a larger government market. Thus a firm may begin to take an active interest in current technical developments within a government laboratory - for example, by performing consultancy work, personal interchange etc. - mainly because it anticipates that current research of this type will lead eventually to production contracts and because it believes that close connections at an early stage with the laboratory will give it an advantage over other firms. There was some evidence from the sample that considerations of this kind are an important feature of firm/laboratory relationships, and, moreover, that nearness to laboratories plays a part in generating and maintaining this type of contact.

It is suggested that both of these features be made the subject of further research, since to the extent that they hold true, this has implications for the advantages and disadvantages associated with nearness to the scientific infrastructure.

(6) It would seem to follow from the results listed in (4) above that scientific and technological activity has definite regional characteristics, thus

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<u>Addendum:</u> Data was requested on sales, profits and employment for the years 1963-67 inclusive, with the objective of generating a rough quantitative picture of the relative performances of the Scottish and English sub-samples as measured by growth of sales, profits/unit of size, and employment. Assuming that the average level of contact with the scientific infrastructure, as between the two samples, remained much the same over this period it would have been possible to make a first-order test of hypothesis 2.

substantiating hypothesis 1. This is borne out by the 'localisation' of virtually all categories of technological and research communications, particularly by the greater amount of contact with government establishments made by the English sample. A proper examination of hypothesis 2 would require a quantitative study of R & D expenditure, profitability and growth. An attempt was made to collect data on this but the poor response rate to this section of the questionnaire has made such an analysis impossible. However, certain considerations suggest that such a study might very well show up the validity of hypothesis 2. These considerations are as follows:

(i) The substitution effect: Scottish industry, it has been noted, has less contact with government establishments than English firms due to the lack of relevant government laboratories in their geographical proximity. Instead they tend to rely more on local academic and library resources. It is evident that this sort of contact, while necessary for technical development, provides less in the way of contacts leading to user-supplier relationships. As many English firms pointed out, personal contacts in government establishments provided avenues by which fresh ideas with migh market potential were transplanted to the industry. This benefit is less likely to accrue to Scottish industry from its substitute contacts. Moreover, close contact with government establishments provides a source of recruitment of new research personnel, which can raise the expertise and quality of work done in the firm's research and development. Again, Scotland is at a disadvantage in this respect, although in the particular sample studied this factor did not appear to be important.

(ii) The cost factor: as noted, both English and Scottish firms seem to place equal importance on attendance at conferences, yet most of these conferences are held in England. Following the discussion in Chapter III, this would imply that more time and expense is expended by Scottish firms in allowing their research staff to attend these conferences. More important, it was shown that relatively more Scottish firms have contacts well outside their own area, involving further time and expense, whereas in England the proximity of government research establishments minimizes these expenses.

(iii) Development contracts: superficially it would appear that since both Scottish and English firms in this sample undertook approximately the same amount of development contract work, that Scotland was no worse off in this respect. However, there are circumstances that even in this aspectshow to the disadvantage of Scottish firms. It is noted in the text that development contracts tend to show a low rate of profitability and so were mainly useful at the initial stages of the firm's life when the firm needs to expand its technological expertise. The larger and more successful firms, on the other hand, tended to reduce their dependence on development contract work in order to concentrate their R & D to meet the demands of the more profitable industrial market. Thus it is to be expected that Scottish firms would in fact tend to do relatively more development contract work on the whole.

(iv) Consultancy opportunities: it was earlier noted that twelve out of fourteen English firms having contact with government establishments also had consultancy arrangements with these agencies, whereas only five out of the ten Scottish firms having such contacts were involved in this type of consultancy arrangement. This suggests that Scottish firms are at a distinct disadvantage in first establishing the contacts, and then must overcome the problems and expenses of geographical separation in maintaining the consultancy agreement.

(v) Finally, it was noted that due to the proximity of government establishments, English firms had no difficulty in obtaining development contract work, whereas Scottish firms had to be more aggresive in pursuing such work with all the added expense and travel involved. The fact that Scottish firms take the trouble to do so despite these disadvantages indicates either that they are still at the state of expanding technology and expertise where development contract work is more valuable, or that they are more dependent on development contract work because of their relative inability to secure the more profitable industrial market contracts.

These points provide circumstantial evidence in favour of hypothesis 2, but clearly the issue is by no means clear-cut. It might, for example, be argued that to the extent the Scottish firms are subsidiaries of companies located close to outside research bodies, the costs of new technologies would be fáirly small since knowledge of this kind would be transmitted through the parent company. In such cases the distance factor might not be important.[1] Evidently a more rigorous examination of this hypothesis should be made and would have to consider the following factors:

(i) Growth: How many new R & D orientated firms are being established in Scotland relative to the south of England? What are the relative rates of R & D expenditure (per employee) and the relative rates of recruitment of new research staff? To what extent are these 'spin-off' companies, and how close are their subsequent relations with the parent laboratory? What are the relative rates of growth of existing science-based firms?

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[1] Although there would still remain the problem of getting into the high technology market and obtaining development contract funding. It was noted in the previous chapter that in the case of one Scottish firm, a subsidiary of an English firm, the bulk of development contracts went to the parent.

(ii) Efficiency: How much of the work done by firms is development contract work, industrial contracts, government production contracts, etc.? What is the relative profitability encountered in these categories? Do these patterns vary according to the geographical locations of firms, and if so, why? What in the view of contracting bodies are the relative capabilities of Scottish vis-a-vis English firms?

(iii) Costs: Clearly it will also be necessary to pin down the costs of technology inputs, since once this is done it will be possible to assess how these vary with time and distance from technology sources. One way of doing this might be to perform a detailed cost analysis of a small number of firms in the expectation of identifying a few proxy variables which could, in turn, be used in a wider analysis.

It is suggested that further research along these lines would be beneficial both in terms of quantifying the importance of the technology factor as well as from the point of view of producing more effective guidelines for policy making. It is hoped that this thesis has gone some way towards identifying the ramifications of this problem area more concretely and in providing a theoretical framework which will facilitate further research.

APPENDIX I

QUESTIONNAIRE.

Dept. of Economics,
Wm. Robertson Building,
George Square,
Edinburgh 8.

Tel. 667-1011 Exts. 6329
6550

We have split this questionnaire into the following four sections. This will improve ease of reply since different sections will probably be filled in by different members of your staff.

I. Description of Establishments:- Here we ask a few general questions concerning your establishment.

II. Extent of Contact Between Establishment and Outside Research Bodies:- The questions here concern mainly visits, recruitment of skilled personnel and other forms of contact. We also ask questions concerning the value which your establishments places on these forms of contact.

III. Research and Development Activity:- Questions here are statistical. From this section we hope to get a more accurate picture of the resources devoted to different types of R & D activity.

IV. General Economic Indicators of Establishment:- This section covers general aspects of your establishments productive activity.

In general we should like you to adhere to the definitions given on the second last page of the questionnaire. This is necessary so as to obtain maximum possible comparability of replies. We do of course welcome any further comments you may care to make whether on specific questions or on the questionnaire itself. Where relevant we have left a certain amount of space for this but should you wish to comment at length please feel free to reply on a separate sheet. It should, of course, be emphasised that all answers will be treated in the strictest confidence.

I. Description of Establishment

(i) Are you a subsidiary of another company? YES/NO

(ii) If "YES" is parent coy. (1) Scottish Based?
(2) English Based?
(3) Based Abroad?

(iii) Have you merged with another coy. during the past five years? YES/NO

(iv) If "YES" (1) give date of merger month year
(2) has this resulted in your R & D activities being transferred out of your establishment? YES/NO/To some extent

II. Extent of Contact Between Firm and Outside Research Bodies (See Note 2).

It is of considerable interest to us to establish as accurately as possible the degree and type of contact. We feel that the questions in this section cover the main points at issue but if in your opinion we have missed anything out please comment.

(i) Of which Research Associations are you a member? (Where none please write "NONE").

(ii) If you maintain regular contact with government research laboratories and/or university departments please give relevant names. (Again if you have no such contact please reply "NONE").

(iii) Do you have contract R & D done for you by outside firms (i.e. firms not affiliated to you)? YES/NO

(iv) The various types of research institution dealt with in this survey maintain a variety of services. It is important for us to assess - at least roughly - the use made by your establishment of these different services. In the tables below, for each category of research institution, rank in percentage terms the use you make of the various services offered.

	Category		
	(1) R.A.'s.	(2) Govt. labs.	(3) Universities
Testing facilities			
Library and Publication facilities (e.g. data sheets)			
Consultancies			
Computing facilities			
Sponsored research			
Other (e.g. attendance at "open days", etc.)			
	100%	100%	100%

(v) We should also like to assess the relative importance <u>to your activities</u> of the contacts you have with outside research bodies. In the table below give:-

(a) The names (abbreviations) of to <u>you</u> the 3 most important institutions in each category.

(b) Rank in percentage terms (for each category the importance of each institution.

(c) Rank in percentage terms the importance of each category.

	Research Associations			Govt. labs.			Universities		
	(1)	(2)	(3)	(1)	(2)	(3)	(1)	(2)	(3)
(a)									
(b)									
(c)									

100%

(vi) Visits made to outside research bodies in 1967

No. of Visits	Research Associations	Government Research Stations	University Departments
NONE			
1-10			
10-50			
50-100			
100-200			
More than 200			

(vii) Visits made by outside research bodies to you in 1967.

No. of Visits	Research Associations	Government Research Stations	University Departments
NONE			
1-10			
10-50			
50-100			
100-200			
More than 200			

(viii) Do you consider that your geographical distance from the main research associations and government research centres relevant to your activities affects:-

(a) Your ability to utilise their services as much as you would like? YES/NO

(b) Your knowledge of the more important technical advances in your field? YES/NO

(ix) Do you have your own technical library? YES/NO

(x) <u>Roughly</u> (to nearest 100) how many books does it contain?

(xi) What technical information services do you make use of, e.g. technical abstracts, dissemination services, etc?

(xii) If you make use of outside library sources place among the following categories the extent to which you make use of them.

	National Lending Library (Boston Spa)	Aslib	University Libraries	Research Libraries	Govt. Research Station Libraries	Public Libraries
Very frequent						
Frequent						
Sporadic						
Nil						

(xiii) Does geographical distance from the sources of technical literature mentioned above affect the extent to which you use them? YES/NO

(xiv) If "YES" to (xiii) please comment giving examples of where this difficulty is felt most acutely.

(xv) How many conferences have members of your staff attended in 1967?

(xvi) Activities of such conferences.

(xvii) On how many occasions during 1967 have you been consulted on your attitude to a particular project being considered by a government laboratory <u>or</u> research association? (If possible give details).

(xviii) How many of your staff have been seconded to outside research bodies over the last 5 years?

(xix) How many staff have been seconded to you from outside research bodies over the last 5 years?

(xx) During 1967 how many problems of a research nature have you referred to:

(a) University Departments?
(b) Government research stations?
(c) Research Associations?

(xxi) In the context of question (xx) would you comment on the usefulness of outside research bodies to your activities giving examples of cases where they have been of some use.

(xxii) What other forms of contact do you have with outside research bodies? (Please comment).

(xxiii) If you have recruited Q.S.E. for R & D work in 1967, please state for each Q.S.E. (see note 4).

Q.S.E.	Name of Institution from which recruited 1	Qualifications 2
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		

1. Where recruit came from private industry please reply "P.I."
2. See note 4. Give "highest" degree obtained.

III. Research and Development Activity (see note 1)

Since we are interested both in the level and the structure of R & D in your industry it would be of considerable help if you could supply the following statistical information. With the exception of questions (i) (1) all questions refer to R & D activity solely. Question (i) (1) refers to all Q.S.E. working in your establishment whether on R & D or on other work. (For definition of Q.S.E. see note 4).

As we are particularly interested in the time structure of R & D we have also requested data for all years back to 1963.

(i) Manpower

Where possible give figures for June 15th of the corresponding year. Otherwise give figures as near to this date as possible mentioning the particular month to which each figure refers.

		1963	1964	1965	1966	1967
Total Qualified Scientific manpower employed by your establishment						
	of which - not employed in R & D					

(ii) Expenditure[1]

		1963	1964	1965	1966	1967
Gross[2] expenditure on R & D						

1. Include all payments to outside bodies (i.e. all research institutions and companies doing R & D for you)

2. Please do not make allowances for depreciation.

(iii) Will answers to questions in this section be on

Accounting year
Calendar year basis?
Fiscal year (see note 3)

(iv) What is your accounting year?

(v) Breakdown of Certain Components of R & D

	1963	1964	1965	1966	1967
Amount paid to outside research institutions. 3					
Royalties, Licence payments, etc. (not to research institutions or parent company)					
Amount paid, if any, to parent company					

3. i.e. Research associations, government labs., etc., Omit general subscriptions to trade associations but include subscriptions to research associations. Also include royalties, licence payments paid to this group.

(vi) Government Contract Work (Only include figures relating to R & D)

	1963	1964	1965	1966	1967
Nos. of Q.S.E. so employed[4]					
Gross Expenditure[5]					

4. See Section (III) (i)

5. See footnotes 1 and 2.

(vii) If you yourself are a parent company some or all of whose R & D is performed by subsidiaries please state:

	1963	1964	1965	1966	1967
Value of work performed by subsidiaries					

(viii) Please give value of R & D work done (if any) on contract for outside bodies (excluding government but including affiliated companies.

	1963	1964	1965	1966	1967
Value of work					

IV. General Economic Indicators of Establishment

(i) Although this questionnaire is mainly concerned with Research and Development it is important that we are able to assess this within the wider context of your establishment's activity. It would therefore be very much appreciated if you would supply the following general information.

	1963	1964	1965	1966	1967
(1) Gross Sales					
(2) Gross Trading Profit					
(3) Total employment					

(ii) Please state whether figures are given on accounting year, calendar year or fiscal year basis.

QUESTIONNAIRE ON RESEARCH AND DEVELOPMENT

Notes and Definitions on the Questionnaire

1. RESEARCH AND DEVELOPMENT

RESEARCH is defined as original investigations towards the discovery of new scientific knowledge, either without short term objectives and/or specific products in view in which case it is termed basic research, or with particular commercial objectives it is called applied research.

DEVELOPMENT is technical activity concerned with non-routine problems encountered in translating research findings into products and processes. This includes construction of pilot plants and design and development of prototypes.

Research and development excludes:

(a) routine analyses, routine inspection, routine production testing and routine quality control.

(b) design and manufacturing units.

(c) tooling up for full-scale production after development of new plant.

(d) production for sale

(e) market research

(f) pre-production of aircraft

(g) selling of an established product

(h) legal work in connection with patent applications

2. OUTSIDE RESEARCH BODIES

These comprise Research Associations, Government Research Establishments, University Departments and any other non-profit making institutions whose activities are mainly concentrated in research and development.

3. ANNUAL DATA

Period covered by data should be kept comparable either on a fiscal, calendar, or accounting year basis. If this is not possible, this should be indicated where a change occurs.

4. QUALIFIED SCIENTIFIC EMPLOYEES (Q.S.E.)

These are defined as graduates with at least a first degree or equivalent qualification in engineering, science or technology. A comprehensive list of qualifications is given overleaf.

List of qualifications in engineering, science and technology

For the purpose of this inquiry a "first degree or equivalent qualification in engineering, science or technology" means one of the following:-

University degree

Diploma in technology

Chartered engineer (C.Eng.)

Associateships or diplomas awarded by the following colleges or former colleges. (Some are now universities):-

	Abbreviation of awards
The Camborne School of Mines	A.C.S.M. or Dip.C.S.M.
The City and Guilds of London Institute	A.C.G.I.
The Cranfield College of Aeronautics (Diploma)	Dip. of
The Heriot Watt College	A.H.W.C.
The Manchester College of Science and Technology	A.M.C.S.T.
The Robert Gordon's Technical College, Aberdeen	
The Royal College of Science (London)	A.R.C.S.
The Royal College of Science (Ireland)	
The Royal School of Mines	A.R.S.M.
The Royal College of Science and Technology, Glasgow.	
The Imperial College of Science and Technology	A.R.C.S., A.R.S.M., A.C.G.I.

Graduate or corporate membership of:

The Royal Aeronautical Society

The Institute of Biology

The Institution of Chemical Engineers

The Royal Institute of Chemistry

The Institution of Civil Engineers

The Institution of Electrical Engineers

The Institution ofElectronic and Radio Engineers

The Institution of Gas Engineers

The Institute of Marine Engineers

The Institution of Mechanical Engineers

Graduate or corporate membership of:- (continued) .....

The Institution of Metallurgists
The Institution of Mining Engineers
The Institution of Mining and Metallurgy
The Institution of Municipal Engineers
The Royal Institution of Naval Architects
The Institute of Physics and Physical Society
The Plastics Institute
The Institution of Production Engineers
The Institution of the Rubber Industry
The Institution of Structural Engineers
The Textile Institute

APPENDIX II

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